THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. I.

No. VI.—JUNE, 1904.

ORIGINAL ARTICLES.

I.—Observations on some of the Foraminifera of the Oceanic Rocks of Trinidad.

By R. J. Lechmere Guppy.

(*Concluded from the May Number, p. 199.*)

(PLATES VIII AND IX.)

THE oceanic beds of Naparima, in Trinidad, contain numerous forms of Foraminifera of great interest, and I propose to make some observations on a few of them. These rocks and their contents were described by me in the Journal of the Geological Society of London, 1892 (vol. xlviii, p. 519). Messrs. Jukes-Browne and Harrison treated of the same subject in the same journal in 1899 (vol. lv, p. 177), and I have given further particulars in the Proceedings of the Zoological Society, 1894 (p. 647), in the Proceedings of the Trinidad Field-Naturalists Club, 1893, and in the Geological Magazine, 1900, p. 322. A few further observations are published in the Proceedings of the Victoria Institute.

On *Gonatosphæra*. (Pl. VIII, Figs. 1–7.)

In the Proceedings of the Zoological Society, 1894, I described a new genus and species from the *Ditrupa*-bed of Pointapier, in Trinidad, under the name of *Gonatosphæra prolata*. The specimens then discovered and described did not enable me to ascertain with any certainty the relationships of the form. Since then I have discovered other specimens which may throw additional light upon these relationships, and I think that there is sufficient interest attached to the subject for me again to bring it forward. The specimens originally discovered were either almost spherical (this being the young form) or a more or less prolate spheroid with a ridge encircling it, as shown in the figs. 14, 16, 19 of the plate appended to the paper quoted. This ridge is the remnant of the wall of the last chamber, which has been broken away in these specimens; while in figs. 15, 17, 18 the last chamber has not been added. The shell begins its existence as a small spherical chamber which in the adult generally shows as a protuberance more or less

marked at the initial or aboral end of the shell. The next segment invests this almost entirely, leaving only a small part of the initial chamber uncovered, and each succeeding segment invests the portion of the shell already formed in the same manner until the last segment is added. This last segment is of a size equal to or larger than the whole of the previous segments together, and does not (as the previously formed ones did) completely invest the preceding segments, but only to the extent of about one-half of the longer diameter or length of the shell. This chamber further differs from the preceding ones in being oval in cross section instead of circular. The mature shell thus described (Pl. VIII, Figs. 1–4) recalls to mind *Lingulina*, which appears to be its nearest relation. From the first the aperture of *Gonatosphæra* is an elongate slit, while the section of the shell at right angles to the axis of its growth is circular. It is therefore evident that an elongate aperture is not necessarily induced by a flattened or compressed contour of the shell, as in *Vaginulina*.

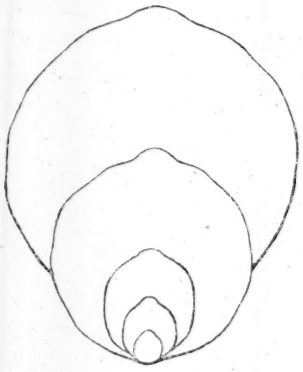


Diagram-Section of *Gonatosphæra*.

As to *Lingulina*, Carpenter says (Introd., p. 164) that it is nothing but a compressed *Nodosaria* whose transverse section is oval, and whose aperture has undergone a corresponding elongation. But the case of *Gonatosphæra* shows that a shell of a circular section may have an elongate slit-like aperture, and that moreover a shell having such a character in its younger stages may develop a subsequent segment of compressed or oval contour, as if indeed the shape of the aperture had ultimately a greater controlling influence than the shape of the shell. I think these facts tend to establish the validity of *Lingulina* as a generic group near which *Gonatosphæra* might be placed in the family Nodosaridæ.

As regards the minuter structure of *Gonatosphæra*, the test is minutely and closely tubulated like that of the unornamented *Nodosariæ*, but it seems to be composed of two or more layers of shell-substance.

Brady (Chall. Rep., p. 517) regards *Lingulina* as representing transition stages between *Nodosaria* and *Frondicularia*. This may

be so; but if so, *Lingulina* comes earlier on the line of development still, retaining more of a frondicularian character than *Nodosaria*. But I could not assert that any of these forms are on the exact line of development: they each represent side branches of such a line of which *Nodosaria* is the last and highest development in its own direction. *Cristellaria, Frondicularia, Uvigerina* (including *Sagrina*) are forms which have branched out of the main line of development between *Polymorphina* and *Nodosaria*.

I should doubt if the fig. 16 of pl. lxv of the "Challenger" Report is *Lingulina carinata*; it looks more like a *Nodosaria*. Goës gives a good figure ("Caribean Rhizopoda," pl. i, fig. 67). Brady's figs. 14, 15 of pl. lxv have the fissurine aperture of the typical *Lingulina*, while 16, 17 have the polymorphine aperture.

This will be an appropriate place to refer to the resemblance between *Fissurina* and *Lingulina*. On consulting Reuss's monograph of *Lagena* (1862, Taf. vi and vii) I noticed at once the resemblance of the aperture and other features of *Fissurina* to *Gonatosphæra*, and I find since that Goës (Carib. Rhiz., p. 58) considers *Fissurina* to be the young of *Lingulina*. I am not by any means sure that this is not so; but the young of *Gonatosphæra*, while possessing the slit-like aperture, differs from *Fissurina* in being spherical instead of compressed.

Remarks on Nodosaridæ.

Dentalina is not a genus at all, as has been shown by Parker, Brady, Rupert Jones, and Carpenter. Indeed, it is not even a variety. Yet, while maintaining *Dentalina* as a group distinct from *Nodosaria*, rhizopodists formerly included under the latter name several entirely distinct forms which are now known under different generic names, e.g., *Lituola* (*Haplostiche*), *Reophax*, *Clavulina*, *Pleurostomella*, *Ellipsoidina*, etc. Possibly a form like that I have named *Stilostomella* may have been the original of Linné's *N. radicula*. Even so lately as 1882 Goës (whose splendid memoirs on Caribean, Arctic, and Scandinavian Rhizopoda are so highly to be valued) has included *Nubecularia* under the name of *Nodosaria* (see Carib. Rhiz., pl. i, figs. 4, 6, 7).

Ludwig Rhumbler (in *Verhandlung der deutschen zoologischen Gesellschaft*, 1897) has pointed out the distinguishing characters of *Nubecularia* and the relationships of that form, which is admittedly distinct from *Nodosaria*. He there explains clearly the transition of *Ophthalmidium* on the one hand into *Spiroloculina*, and on the other into *Nubecularia*. His explanation is well supported by the facts. And here we may ask if *Articulina* is not the same generically as *Nubecularia*?

Amphicoryne is no more a genus than *Dentalina*. It is simply a *Nodosaria* in which the embryonic character of *Polymorphina* passing into *Cristellaria* has been retained until a late stage in the growth of the organism. And it is this occasional persistence of an embryonic character which shows us the true phylogeny of an organism, in this case *Nodosaria*, as indicated in my paper of 1894 (P.Z.S.).

The term *Sagrina* is superfluous, as pointed out by Brady (Chall. Rep., p. 580). The name *Uvigerina* sufficiently covers the forms so named. *Uvigerina* as well as *Spiroplecta* shows a cristellarian commencement. *Uvigerina* is the form connecting *Polymorphina* through *Cristellaria* with *Nodosaria*, while *Spiroplecta* is the analogous arenaceous form. The biserial and triserial forms of the arenaceous Foraminifera passing into uniserial forms are due to their descent from *Polymorphina*. Very minute Textularians as well as *Bolivina* often show a similar kind of commencement.

Goës ("Arctic and Scandinavian Rhizopoda," p. 6) gives figures of three forms of *Frondicularia*, two of which closely resemble those I have given in P.Z.S., 1894, pl. xli, figs. 3, 4. His observations are entirely in accordance with mine. He says: "Thus in this instance we have before us the plainest proceeding of evolution from one type to another, in which an earlier type becomes larva for another type. At last the larval condition is reduced to a single segment, and a new form has originated seemingly standing without much morphological connection with its origin." He further remarks that the smallest embryo segments do not always give rise to a dimorphous form, but at once assume the mature arrangement of the segments. This is exactly what I pointed out in my paper above referred to. Thus *Flabellina* is not a genus, but merely represents those Frondicularias that retain an embryonic cristellarian commencement. That these were more abundant in the past than they are at present is natural, for the tendency would ever be for the embryonic form to pass at once to the mature form. And this condition is not confined to Foraminifera, but is exhibited in species belonging to Crustacea, Insecta, and Mollusca. These, as they increase by interstitial and not by incremental growth, do not permanently show the embryonic form, though Mollusca do so to some extent. They pass through the embryonic stages, and the embryonic condition can only be observed while they are passing through it. But Foraminifera, growing by stages and each stage being retained as part of the mature organism, show more or less all the stages they have passed through from the first segment.

We have not yet arrived at a true appreciation of the full significance of the various characters of Foraminifera. Doubtless we shall do so after careful study and comparison. Without being able myself to point out all the significance of the facts, I may still advert to some of them.

The close affinity between *Nodosaria*, *Uvigerina*, and *Polymorphina* has long been acknowledged by rhizopodists. It is stated by Carpenter (Introd., p. 168). It is only the order of their development and affinity that has been matter of doubt. The aperture of *Nodosaria* is normally circular with radiating fissures or grooves. This aperture is characteristic of *Polymorphina*, *Cristellaria*, and *Frondicularia*. In some Nodosarians the radiating fissures are obsolete or disappear, and the aperture becomes simply circular, often at the end of a neck which is usually everted and encircled by ridges spiral or circular. In other forms, the test being oval in

transverse section, the aperture becomes a slit, the animal taking on a compressed form, e.g. *Vaginulina*.

The old ideas about the phylogeny of *Nodosaria* arose from the fact that it was so easy to imagine the unicellular *Lagena* budding another segment on to itself, which process, if continued, would result in an organism resembling a *Nodosaria*. Carpenter says (Introd., p. 165) that the relationship of the *Nodosaria* to the unilocular *Lagena* "is extremely obvious, many forms of *Nodosaria* being in all essential particulars *Lagenæ*, of which the segments that are successively formed by gemmation have remained in continuity with each other." But I have seldom found a *Lagena* that I could mistake for the chamber of a *Nodosaria*, or the broken-off chamber of a *Nodosaria* which I could mistake for a *Lagena*. And, indeed, if such were the descent of *Nodosaria* the existence of the amphicoryne form would be inexplicable. In order to supply an explanation rhizopodists have been compelled to assume an extreme instability of character in Foraminifera which is beyond the fact. It may be added that the aperture of a typical *Lagena* seldom resembles that of a *Polymorphina* or *Nodosaria*. The fine series of figures given by Goës ("Arctic and Scandinavian Foraminifera," pls. ix–xiii) shows the persistency of the polymorphine aperture in forms descended from the polymorphine type. The "Challenger" figures are not excelled by any in fidelity to nature, and they show the same feature. So likewise with the figures given by Flint ("Recent Foraminifera," Smithsonian Institution, 1899). And Rupert Jones, in the Monthly Microscopical Journal (1876), gives some good figures showing the typical form of the nodosarian aperture to compare with that of *Lingulina costata* which he figures at pl. cxxix, fig. 11.

Nodosaria hispida and others.

I have retained the name of *Nodosaria hispida* for one of the most abundant Nodosarians of the oceanic beds of Naparima in Trinidad, and though I was at first doubtful of this determination, it seems confirmed by Flint's fig. 1 of his pl. lvii and fig. 4 of pl. lvi. In our *N. hispida* (Pl. VIII, Figs. 10, 11) the segments, though spherical internally, and therefore of the same shape as those of the typical *N. hispida*, are closely connected externally by shell-substance filling up the sutures, one or two only of the latter segments being distinctly separated by a sunken suture or constriction. The shell is thus somewhat fusiform in outline; it is often straight, but occasionally curved or dentaline. The surface is covered with tubercles or spines, and this character is pretty evenly maintained. The aperture is circular, and is situated in a short doubly-lipped neck as in *N. abyssorum* and other species. In beds which seem to have been deposited in shallower water the tubercles become bolder and more elongate, and this form is called *N. conspurcata* (Reuss, Tert. Foram., pl. ii, figs. 10–12). Many of the specimens recall *N. verruculosa*, Neug., and are not distinguishable by any trustworthy character. *N. rugosa*, Orb. (For. Cuba), appears to be a poor example of the same species. *N. hirsuta*, Orb., Parker, Jones & Brady (Ann. & Mag.

Nat. Hist., Sept. 1871, pl. ix, fig. 45), is another form of the same species; indeed, it is by those authors (p. 154) assigned to *hispida*. The minute structure of the test is probably similar to that of other Nodosarians, that is to say, minutely and closely tubulated. But the appearance under the microscope is similar to that of *Orbulina*, as figured by Carpenter (Introduction, pl. xii, fig. 8). What appear to be large pores are probably the transparent shell-substance of the tubercles.

Other Nodosarians of the Naparima oceanic beds are worthy of a notice. These are specially *N. abyssorum*, *N. longiscata*, and *N. arundinea*. Neither *N. longiscata* nor *N. arundinea* are noticed in the "Challenger" Report, but both are recorded from the London Clay and Vienna Basin; also from the oceanic beds of Barbados. *N. arundinea* (Pl. VIII, Figs. 14, 15) consists of a long tube-like body with occasional slight constrictions and inflations. In its general form it resembles *Rhabdammina*, while *N. longiscata* resembles *Hyperammina*. The shell-structure of both species is minutely and closely tubulated as in other Nodosarians, and shows no sign of any arenaceous condition. I have not access to any satisfactory figures of either species. *N. longiscata* (Pl. VIII, Figs. 12, 13) generally consists of a sub-globular initial segment succeeded by one or two, rarely three, extremely elongate segments, scarcely separated by a more or less evident constriction. Some of the simpler forms recall certain forms of *Lagena vulgaris*, although they cannot be mistaken for *Lagenæ*. It is possible that *N. arundinea* is really the same as *N. longiscata*, but I have not been able to prove this. The specimens of the former showing the nearest approach to the latter are somewhat like a thermometer-tube in shape.

Nodosaria abyssorum (Pl. VIII, Figs. 8, 9) was described by Brady, who in Chall. Rep., p. 504, says of it, "It is not by any means certain that it really belongs to the genus *Nodosaria*, that it is not rather a deep-sea variety of *Sagrina*." I am of opinion that it is a *Nodosaria*, the polymucronate apex, by which character it is distinguished from all other Nodosarias, being in no way like the apical portion of a *Sagrina* (*Uvigerina*).

Nodosaria abyssorum was found at Challenger Station 296, south-west of Juan Fernandez, at a depth of 1,825 fathoms, and, so far as I can ascertain, it is not recorded from any other locality. It is not mentioned either by Brady or Chapman in their lists of Barbados Fossil Foraminifera. It occurs in the Naparima oceanic beds, and specimens in all respects similar to those figured by Brady (Chall. Rep., pl. lxiii, figs. 8, 9) are common. Indeed, that and *N. hispida* are the two most abundant and easily recognized Nodosarias found in these rocks, and it was owing to the frequency of their occurrence that I called some of the beds *Nodosaria* beds. The non-occurrence of *N. abyssorum* in the Barbados oceanic beds is remarkable, as their fauna is almost identical with that of the Naparima beds of Trinidad.

In the identification of Reuss's species *retrorsa*, it appears to me that Brady has not made use of his usual acumen. Brady's figure (Chall. Rep., pl. lxiii, fig. 7) represents what I take to be a slender

form of *abyssorum*. Reuss's figure (Sitzungsb. d. k. Akad. Wiss. Wien, vol. xlviii, 1863, p. 46, pl. iii, fig. 27) shows a very different form. The species seems to have been based on a single fragment with imperfect first and last chambers; there is therefore nothing from which to infer a polymucronate apex. But this is the essential character of *N. abyssorum*, and such an apex is clearly shown in Brady's figure above quoted, and I know of no other *Nodosaria* which exhibits this feature; I take it, therefore, that Brady's *retrorsa* (not Reuss's) must be considered a variety of *abyssorum*, and thus the range of distribution of *N. abyssorum* (in a varietal form) is extended to the Ki Islands at a depth of 580 fathoms. *Nodosaria abyssorum* is so distinct a species that one seldom has any doubt about any specimen of it. The character of its apex or initial end is so marked, and its other characters are usually constant.

It is remarkable that the nearest relation of an echinoderm (*Cystechinus*) found in the oceanic rocks of Barbados is also from the neighbourhood of Juan Fernandez, at a depth of over 2,000 fathoms.

Concluding Remarks.

I have at the present only a few further remarks to make about the Foraminifera of the oceanic beds. *Pulvinulina Menardi* and *Virgulina* are remarkable for their absence from these deposits. The record of the occurrence of an example of *P. Menardi* by me was an error. *Pulvinulina canariensis* (a near relation of *P. Menardi*) occurs in the Pointapier *Ditrupa*-bed and in the Radiolarian marls of Naparima, and it is recorded from one locality in Barbados, but I have not found it in the foraminiferal beds of Naparima. (See the observations of Parker & Rupert Jones, "North Atlantic and Arctic Foraminifera," 1864, p. 395.) *Virgulina* has not occurred either in Barbados or Trinidad. Is it possible that this may be an indication of the age of these beds, while the absence of *Pulvinulina Menardi* may be due to the extension of the continent to the north-eastward, as indicated in my papers of 1892 and 1902?

The list of Foraminifera from Bissex Hill, Barbados, given by F. Chapman (Journ. Geol. Soc. London, 1898, p. 550), is almost identical with ours from the Naparima oceanic beds. The few differences are mainly due to the determination of forms under different names by each of us. The only significant difference is the absence of *Orbulina* from the Barbados oceanic beds. It is abundant in the oceanic beds of Trinidad and in the Pointapier *Ditrupa*-bed.

It may be useful to repeat here the conclusions as to depth of water and other physical conditions arrived at by Messrs. Harrison and Jukes-Browne as the result of their examination of the geology of Barbados (published by authority of the Barbadian Legislature, 1890).

"In the calcareous earths the shells of Foraminifera are common, most of them belonging to species which are now found at considerable depths . . . . the assemblage of species being such as might now be found in Atlantic ooze at a depth of 1,000 fathoms.

There can be no doubt, therefore, that these chalky earths and limestones were formed in the same manner and at the same depths as the chalky muds which are now being formed in many parts of the Atlantic and Pacific Oceans. The siliceous radiolarian earths indicate even a greater depth than the calcareous deposits. Radiolarian ooze does not exist in the Atlantic, but is found in the Pacific and Indian Oceans at depths of from 2,000 to 4,000 fathoms. Its existence in Barbados therefore suggests the idea that it was formed in a deep basin which was open to the Pacific as well as to the Atlantic, and consequently at a time when the Isthmus of Panama did not exist."

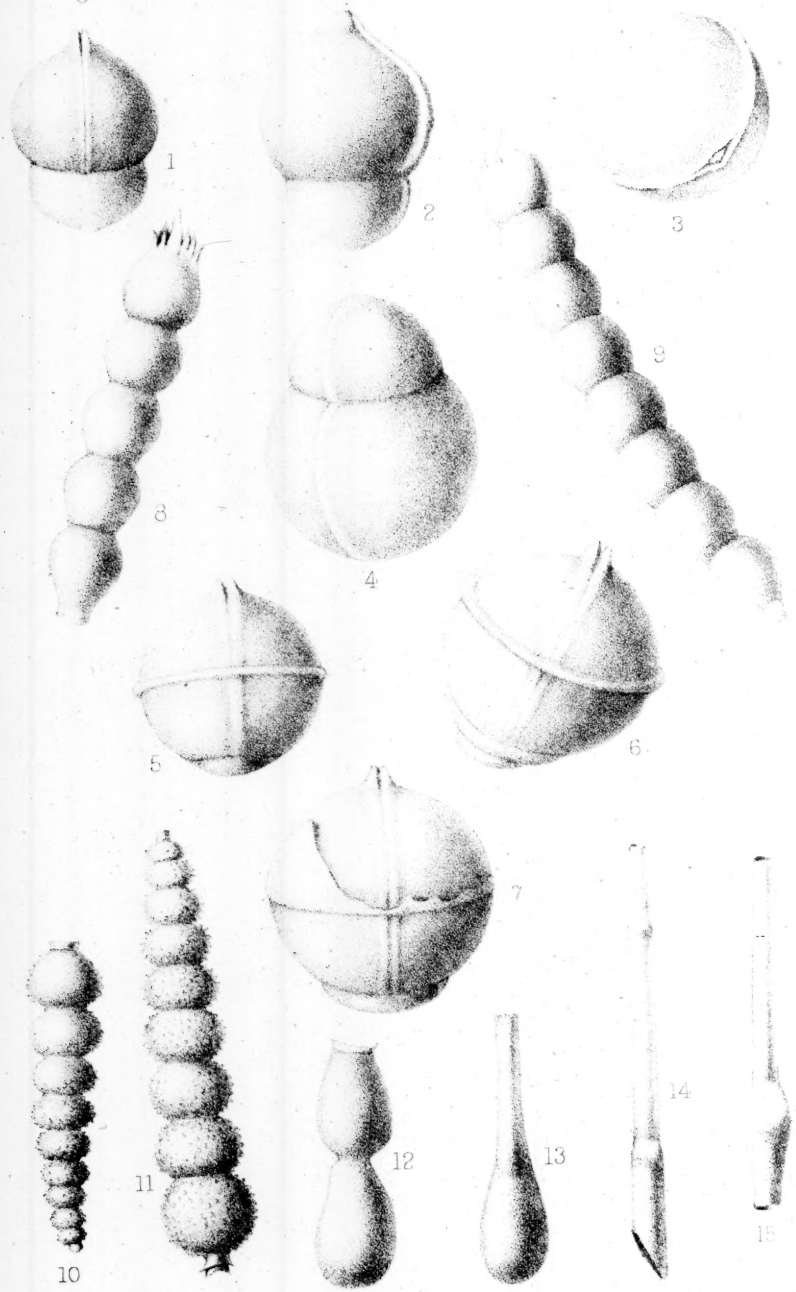
These conclusions are exactly applicable to the Naparima oceanic beds. But it must be admitted that the enormous amount of change in the physical geography of this portion of the earth's surface which would be required to satisfy these conclusions makes one feel inclined to be contented to accept a less depth of water than that above indicated, if other circumstances can be shown to admit of this. And I think that this can be done; for the amount of clastic material found in certain of the beds (Nariva Series) betokens (as I may hereafter have an opportunity of showing) nearness of land and a shallower sea than might apparently be indicated by the Microzoic fauna.

Note on the foregoing Paper.

Ludwig Rhumbler has (in *Nachrichten Gesellschaft der Wissenschaften zu Göttingen*, 1895, p. 51, and the paper before cited) two very noteworthy papers on the phylogeny of Foraminifera. In the first of these papers he has propounded a very ingenious systematic arrangement of the families. My researches have not enabled me to say how much of his system is founded in fact, but the observations in the foregoing paper show that so far as regards the phylogeny of *Nodosaria* the system is not exactly applicable. Indeed, it is most likely that all triserial and biserial Foraminifera have been evolved from *Polymorphina*, their triserial and biserial nature being in fact due to that parentage, the primordial form being a unicellular *Polymorphina*.

The theory that *Nodosaria* is derived directly from *Lagena*, and that *Cristellaria* and related forms are derived from *Nodosaria*, is the result of an idea that complex forms must be evolved from simpler ones, and that a simple form cannot be evolved from a composite one. The fact cannot be denied, however, that in *Clavulina*, *Bigenerina*, *Uvigerina*, etc., the simpler form follows on the more complex one.

Rhumbler's observations tend, I think, to confirm mine respecting the so-called gemmation or colony-building of Foraminifera. This theory appears to me to be founded on a misconception of the real mode of growth of the foraminifer. The body of the foraminifer, like that of the mollusc, grows by interstitial increase, while the shell is extended by incremental increase. To accommodate the integument to the increase of size, the insect and the crustacean exuviate their old shells and form new ones. But the mollusc and the foraminifer,



L. Guppy jr. del.
G. M. Woodward lith.

West, Newman imp.

Trinidad Foraminifera.

instead of doing this, develop an additional portion, segment, or cell to accommodate the increased size of the body. This is incremental growth as contrasted with the interstitial growth of the soft parts. The idea, therefore, that a polythalamous foraminifer is a colony and not a single organism is not well founded. No doubt the idea is derived from the cœlenterata, where separate polyps are developed one from another, the whole mass of polyps nevertheless remaining in union and forming what is designated as a colony. In one sense perhaps every animal may be regarded as a colony. But the foraminifer is not more so than a Nautilus.

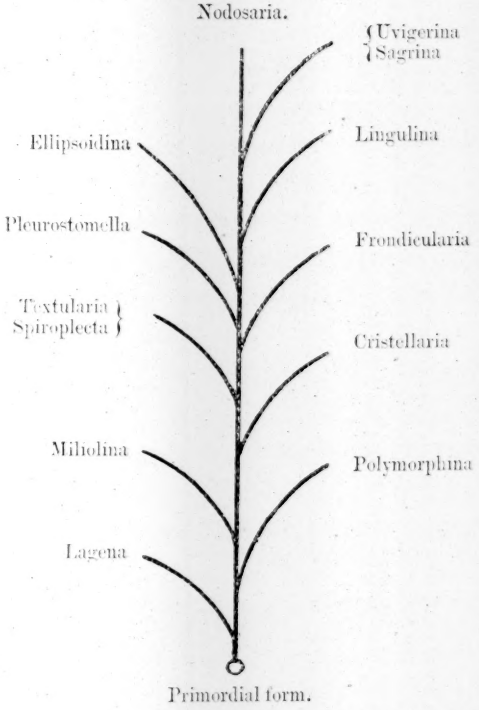


Diagram to illustrate the Phylogeny of *Nodosaria* and allied forms.

EXPLANATION OF PLATES VIII AND IX.

Plate VIII.

Figs. 1–4.—*Gonatosphæra prolata.* Views of different specimens of the perfect adult form.

,, 5–7.—Specimens in which the last chamber has been broken away, leaving the ridge where the wall of the last chamber was adherent to the previous segment. In Fig. 7 a portion of the wall of the last chamber still remains.

,, 8, 9.—*Nodosaria abyssorum.*

,, 10, 11.—*Nodosaria hispida.*

Figs. 12, 13.—*Nodosaria longiscata.*

,, 14, 15.—*Nodosaria arundinea.*

PLATE IX.

FIG. 1.—*Clavulina Soldanii.*
,, 2.—*Reophax scorpiurus.*
,, 3.—*Cyclamina deformis.*
,, 4.—*Miliolina macilenta.*
,, 5.—*Spiroloculina tenuiseptata.*
,, 6.—*Textularia sagittula.*
,, 7.—*Textularia carinata.*
,, 8.—*Textularia trochus.*
,, 9.—*Nodosaria raphanistrum.*
FIG. 10.—*Nodosaria obliqua.*
,, 11. *Nodosaria soluta.*
,, 12.—*Cristellaria rotulata.*
,, 13.—*Cristellaria aculeata.*
,, 14.—*Uvigerina raphanus.*
,, 15.—*Planorbulina elegans.*
,, 16.—*Pulvinulina elegans.*
,, 17.—*Textularia aspera.*
,, 18.—*Textularia gramen.*

II.—OCCURRENCE OF MIOCENE ROCKS IN EASTERN SINAI.[1]

By W. F. HUME, D.Sc. (Lond.), A.R.S.M., F.G.S.

THE study of Egyptian geology during the last few years has thrown a flood of light on the former extension of the Mediterranean southward in Miocene times. Th. Fuchs,[2] in examining the rich collections from the Cairo–Suez desert and the oasis of Siwah, recognized that the Miocene strata had a close resemblance to those of the Vienna Basin, and corresponded to the Grunder Beds at the base of the second Mediterranean stage, or the lower portion of the Middle Miocene. Later L. H. Mitchell,[3] when studying the neighbourhood of Ras Jemsa and Jebel Zeit in 1887, obtained a number of large oysters, which Meyer-Eymar recognized as *Ostrea crassissima* and *Ostrea gigantea*, and which were regarded as proving the existence of strata of Upper Miocene age along the western border of the Suez Gulf. From these results Blanckenhorn[4] concluded that the Gulf of Suez must have been a Mediterranean bay in Miocene times, and further noted (Zeitsch. Deutsch. Geol. Gesell., Band liii, 1901, p. 79) that characteristic Miocene Pectens, viz. *Pecten Sub-Malvinæ*, occurred in the collection made by Barron at Abu Sha'ar. He further formed the opinion that all the marine Miocene strata in Egypt were of the age assigned to them by Fuchs (see also Barron & Hume, "Miocene Rocks in Eastern Desert," Memoir of Egypt. Geol. Surv., 1902, pp. 159–165).

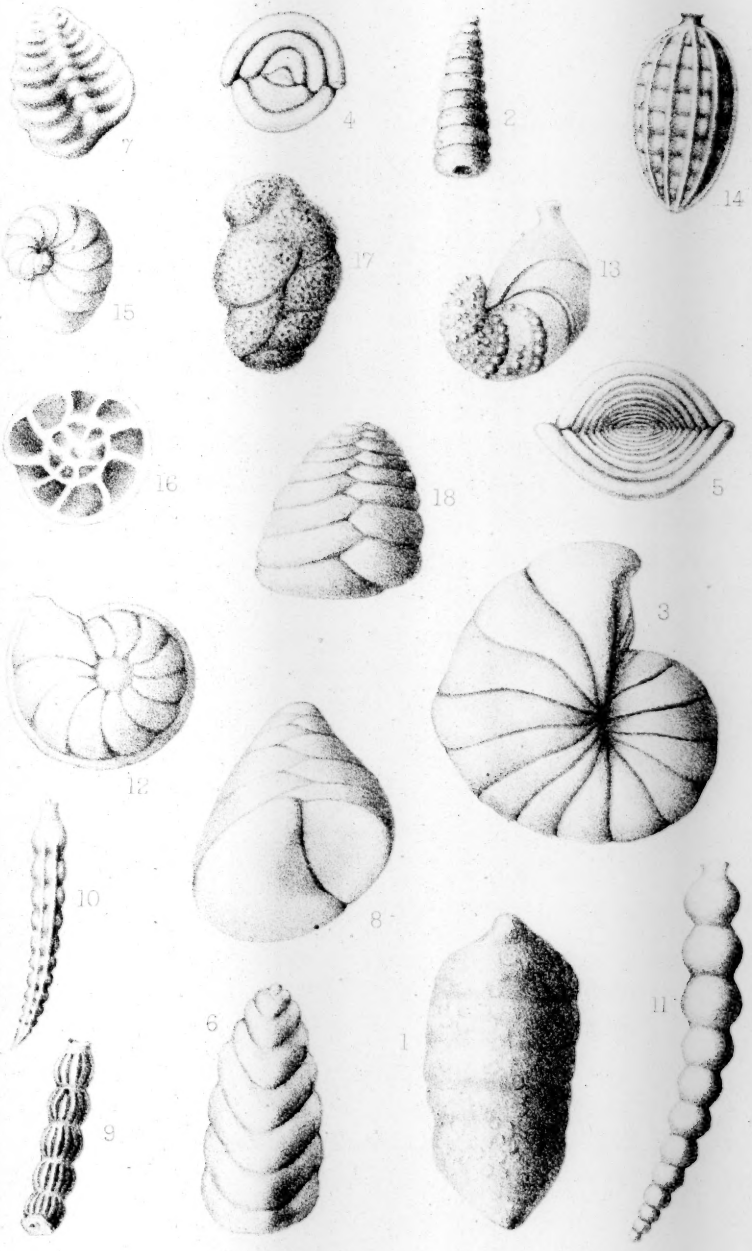
Strata of similar age were first found in the Sinai Peninsula by Bauerman in 1868 ("Note on a Geological Reconnaissance in Arabia Petræa," Quart. Journ. Geol. Soc., xxv, pp. 24 and 37), and were subsequently examined by Rothpletz ("Stratigraphisches von der Sinai-Halbinsel," N. Jahrb. für Min., 1893, i, p. 103) and Blanckenhorn (Zeitsch. Deutsch. Geol. Gesell., Bd. liii, 1, 1901, p. 75), the latter tracing them from Wadi Gharandel to the mouth of Wadi Tayiba. When examining the southern end of Eastern Sinai, the present

[1] Published by permission of Sir W. Garstin, Under-Secretary of State for Public Works, Egypt, and Captain H. G. Lyons, R.E., Director-General Survey Department, Cairo.

[2] Th. Fuchs, "Beiträge zur Kenntnis der Miocaenfauna, etc.," in Zittel, "Erforschung der Libyschen Wüste," p. 36.

[3] L. H. Mitchell: "Ras Gemsah and Jebel Zeit: Report on their Geology and Petroleum"; Cairo, 1887.

[4] M. Blanckenhorn, "Die Struckturlinien Syriens und des Rothen Meeres": Richthofen Festschritt, Berlin, 1893.



J. Guppy jr. del.
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Trinidad Foraminifera.

writer was surprised to find beds of large oysters in the terraces a few kilometres south of Sherm, at the foot of a marked transverse range, the Jebel Zafara, these being especially marked in Wadi Khoraiyah. On comparing these with the oysters from the Miocene west of the Suez Gulf, there seemed little doubt that the species were identical, but to fully establish the point the specimens were submitted to Dr. Blanckenhorn, who has recognized the oysters of Wadi Khoraiyah as *Ostrea Virleti*, Desh., and typical *Ostrea gingensis*, var. *setensis*, Blanck., while *Ostrea Virleti* was further recorded from a limestone above brown sands between Nebk and Sherm. The latter was evidently derived from the older Miocene series, but is now associated with Pleistocene fossils.

In a paper on the geology of Eastern Sinai (International Geol. Congress, Paris, 1901) the writer called special attention to the existence of certain highly tilted beds occurring at the southern end of the peninsula, in most cases standing well back from the sea and having undergone extreme alteration. South of Jebel Zafara these are well developed, forming a series of yellow hills close to the junction of the igneous rocks, and rising nearly 200 metres above the sea. Here the beds have been tilted to an extraordinary extent, in some cases dipping from 30° to 60° E., and being apparently connected with a longitudinal fault of importance. In the paper above-mentioned it was further pointed out that their appearance recalled the altered coral-reefs of this region, and that they still contained oysters and casts of *Pecten*, but their age was not then definitely stated. The identification of the oysters of Khoraiyah leaves little doubt, however, that these beds also are of Miocene age, and we therefore arrive at the conclusion that the *Older Tilted Reefs at the southern end of the Gulf of Akaba are Miocene in age* and agree with those on the western side of the Gulf of Suez. Dr. Blanckenhorn has made some observations in sending the specimens which it may be of interest to quote here. "It is to be assumed that *Lithodomus* (*Botula*) *cinnamomea*, *Gastrochæna Retzi*, oysters of the *crassissima–gingensis* group, *Lucina* sp. aff. *tigrina*, and corals like *Cyphastræa chalcidicum*, etc., persisted from Miocene to Pleistocene times in the Erythræan region in a salt 'Binnensee' situated somewhere in the deepest part of the Gulf of Suez. In the Upper Pliocene there was the second invasion of Mediterranean forms into the Erythræan region. At this point there came in *Pecten varius*, *Pecten benedictus*, *Cerithium conicum*, *Ostrea cucullata* and *plicatula*, *Arca lactea*, etc. Possibly in the neighbourhood of Sinai there may be a place which still contains remains of this more continental transition period between the Middle Miocene (Helvetian) and the Upper Pliocene. Might the No. 4798 [this is the above-mentioned *Ostrea gingengis*, var. *setensis*, of Wadi Khoraiyah] be included here?"

Having seen the deposits from both the Eastern Desert of Egypt and Eastern Sinai, it seems to me impossible to separate the two, and if the former are Helvetian the latter must also be of the same age, so that the conclusion is forced on us that the Gulf of Akaba (at least in part) was already occupied by the sea at this early

period. The question thus opened is a wide one, and whatever its solution demands far-reaching hypotheses. Did the Miocene sea extend over the whole peninsula, and are these but faulted relics of this Mediterranean advance, or was the present configuration of this district so far outlined that two arms of the sea already bounded the Sinai peninsula, though connected with the Mediterranean instead of the Red Sea, as at the present day? In the Central Sinai ranges no traces of such strata have been met with in the fault-valleys, and the final answer will probably only be obtained when the plateau of El Tih has been more closely examined. The other alternative appears to be that fault or rift action had begun at a far earlier date than is usually assumed.

In any case it can now be definitely stated that *Miocene* strata of well-marked character are also present in the Gulf of Akaba area, and Barron permits me to add that he has found *Pecten*, *Ostrea*, and *Heterostegina* beds of the same age to be present in the whole sedimentary area of the west of Sinai. We both agree in regarding the raised reef at Ras Mohammed as belonging to the same stage, a view which is supported to a certain extent by Blanckenhorn's identification of the fossils sent from this locality, though the latter are always poorly preserved.

III.—Hot Springs.

By Ernest H. L. Schwarz, A.R.C.S., F.G.S.,
Of the Geological Survey, Cape of Good Hope.

THROUGH the great kindness of Professor Suess I have received the full text of his paper on Hot Springs, read before the Congress of Naturforscher und Aerzte[1] held last year in Karlsbad, in which he adduces very strong arguments in favour of their being due to vapours given off from the molten interior of the earth as it gradually cools. I have for a long time been observing the hot springs that occur in the Cape Colony, and had come to the conclusion that they were surface-waters that had sunk deep into the earth's crust, and were returned heated in consequence of their having been in the neighbourhood of potential fusion of the rocks. This latter view I alluded to in a recent paper,[2] and I do not like to have to give up a long-cherished idea before submitting to the public a statement of the reasons that led me to my view of the subject.

The first point is the position in which we find the hot springs of the Colony. Those at Aliwal North occur apparently in the Beaufort Beds, and those at Malmesbury in the old clay-slates and granite, but all the others come out at or near the junction of the Table Mountain Sandstone with the Bokkeveld Beds. The following is a list of those that I have visited:—Caledon; Montagu; Brand Vlei, on the Worcester–Villiersdorp road; Warm Water, on the road

[1] "Prometheus," vol. xiv, Nos. 690, 691, 692, beginning p. 209, Berlin, 1903; abstract in Geographical Journal, vol. xx, p. 517.

[2] "An unrecognised Agent in the Deformation of Rocks": Trans. S. African Phil. Soc., p. 391, Cape Town, 1903.

from Montagu to Ladismith; Warm Water, a spring in the bed of the Ondtshoorn Oliphant's River, just before it enters the gorge through the Samka Hills; Tover Water in Uniondale Division, south of the Zwartebergen; and Warm Water in the upper part of the Clanwilliam Oliphant's River. Brand Vlei is the hottest spring, the water being sufficient to scald pigs with—an unscientific way of expressing things, perhaps, but preferable, I think, to giving the readings from the thermometer of commerce; the water from the spring in the valley of the Clanwilliam Oliphant's River has to be cooled down before one can get into it; but the rest are just so hot that one can cautiously enter the water as it issues. Most of them contain iron in solution, but Brand Vlei does not deposit anything. In the same position there are very many ordinary springs, and, in fact, the hot springs are each accompanied by a cold spring that issues alongside. In the next two series of beds, the

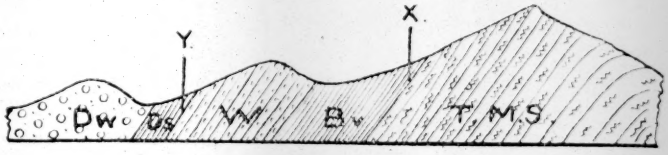

FIG. 1.—The succession of the beds in the folded region of the Cape Colony. T.M.S., Table Mountain Series; Bv., Bokkeveld Series (Devonian); W., Witteberg Series; Ds., shales below the Dwyka Conglomerate, Dw. X indicates the position where most of the hot springs of the colony come out; it is a well-recognized water-zone. Y is a corresponding water-zone, but no hot springs come out here, though some are highly ferruginous.

Witteberg and the Dwyka series, the former corresponding in character to the Table Mountain Sandstone, and the latter, as far as the lower shales are concerned, to the Bokkeveld Beds, there is a water-zone at the junction, but owing to the less porous nature of the sandstones the springs are very weak and scarce, though some of them are charged with iron, as at Hartnek's Kloof in the Ceres Karroo; the Witteberg–Dwyka springs are never warm. Besides the hot and the cold and the ferruginous springs, we have in the Colony what are known as sand-fountains, which are, as it were, quicksands inverted, for if a stone is pressed into the moist sand it is promptly returned to the surface; should, however, the spring dry up, owing to the drought, the sand-fountains become true quicksands, and cattle going down to drink are quickly entombed. The sand-fountains occur on the junction of the sandstone formations with the overlying shale beds, but the kruid- or stink-fountains, that is to say, those giving off sulphuretted hydrogen, usually occur away from the mountains. Hot springs occur also in the Table Mountain Sandstone in the bed of the Umzimvubu River, near Pont St. John's, and in the Molteno Beds in the bed of the Kenigha River, near the trading station called Kenigha, but these occur irregularly, without any apparent general cause for their appearance. What I wish to call attention to is that there is a great water-zone

at the junction of the Table Mountain Sandstone and the Bokkeveld Beds, and that ordinary springs, which are certainly the water returned to the surface after a short course underground, occur plentifully along it; the hot springs, instead of taking advantage of veins or fissures, come up in exactly the same way. In other words, the hot springs at the surface occur in the same manner as the cold ones, though it is probable that the hot water reaches the water-zone through underground fissures. When there is a good exposure of the Malmesbury clay-slates, from which the Table Mountain Sandstone has been removed by denudation, the veins of quartz are seen everywhere traversing the rock; north of Van Rhynsdorp, indeed, the surface of the ground is so covered with the white quartz which has weathered out of these veins that it looks as if there had been a heavy fall of snow. My first point, therefore, will depend on whether these fissures are being filled by materials from solution in water which is essentially different in origin to that of the surface springs.

As far as I am aware, no heavy metals, such as gold or mercury, have been found in connection with lavas.[1] Dykes are known to contain them in workable quantities, as in some of the acid veins in Australia; I have even found gold in the dolerite traversing the banket-reefs on the Rand; also the precious metal occurs in some of the volcanic tuffs of Australia, for instance on the Lyndhurst goldfield, but in all these cases there is a very strong suspicion, or some would say conclusive proof, that the gold has got into the rock by absorption and infiltration, and is not original. At Ongeluk's Nek, in the Drakensberg, there was a very great gold-rush at one time, and the lavas were prospected to the topmost peaks of the range, but without result.[2] Should volcanoes be the orifices of pipes that go down to the inmost recesses of the earth, then one would expect oceanic islands and volcanic areas to be the best places to prospect in, instead of the older sedimentary rocks, and the difference to my mind proves that the mineralized beds have been carried beneath the earth's surface to greater depths than those at which volcanoes have their origin. All this seems to point to an essential difference between volcanoes and hot springs. The latter do deposit gold and other heavy metals from solution, as one can actually see now in progress at the Steamboat Springs in Nevada,[3] though the process is one that usually goes on at a very great depth. The hot springs may be due to expulsion by superheated vapour, and it seems an obvious explanation when we see the enormous pressure which steam will exert. In the interior of

[1 Reference may be made to the occurrence of native iron, which has been discovered in considerable quantities at Ovifak, Disko Island, Greenland, and which was at one time supposed to be of meteoric origin, but has since been shown to be disseminated through an eruptive basaltic rock on the spot, and must therefore have come to the surface from a deep-seated source in the interior of the earth. (See K. J. V. Steenstrup in Mineralogical Magazine, July, 1884, vol. vi, p. 1.)—Edit. Geol. Mag.]

[2] Ann. Report Geol. Commission for 1902, Cape Town, 1903, p. 46.

[3] Becker: U.S. Geol. Surv., Mon. 13, 1888.

the earth, however, things are in equilibrium; enormous pressures do exist, but they are produced by the superincumbent masses of rock, and the heat that there is at great depths only exists as a mode of energy which helps in balancing the stress. In other words, looked at from an isostatic point of view, there is no surplus energy in the earth's interior to expel the large quantities of water that come up in hot springs; these must rise in accordance with hydrostatic laws. The argument from the permanency of such springs, which would seem to imply that they are independent of supplies from the surface, can be met with the counter argument that, as they are hot, and must therefore come up from great depths, the area with which they are in hydrostatic connection is sufficiently large to ensure a constant average.

The third point is that raised in my paper on the deformation of rocks, referred to above. It is that though lavas do undoubtedly contain a large quantity of water-vapour, nevertheless this water-vapour is held up in occlusion, and is unavailable unless the lava has cooled down to a certain point. My inference was drawn from a study of the Drakensberg lavas, in which there are very large vesicles in the shape of branching pipes; these occur only on the bottom of the lava-flows, the topmost portions having got rid of most of their water-vapour and show only the normal rounded vesicles. This seemed to me a sufficient proof that the water-vapour was held in actual occlusion, just as gases are held in occlusion in furnace slag.[1] For when the lava was flowing, the pressure on the surface being reduced from that of many atmospheres in the chimney of the volcano to that of one atmosphere, one would naturally expect that all the water-vapour would explosively escape; this, however, was not the case, or else the vesicles would not have been formed. What happened was this: the topmost layers of the lava-flow cooled down to the expulsion point, and then only gave off their occluded water-vapour; later, the lower layers cooled down and endeavoured to get rid of their water-vapour, but the upper layers had already cooled below the expulsion point, and were therefore unable to absorb and pass on that which the lower layers tried to get rid of; the consequence was that the water-vapour was obliged to come out from the body of the molten rock, and had to force this apart in the shape of the very large vesicles in order to accommodate itself. From a study of the microscopic characters of the lavas I was led to infer that the temperature of the extrusion of the water-vapour was a little above the melting-point of labradorite, that is to say, somewhere in the neighbourhood of 1200° C. The whole of this question is one that can be settled by laboratory experiment, and I am earnestly hoping that there will be early opportunities of doing such work.

My fourth point is in connection with the moon. That body was separated from the earth at a time when the water now existing on the surface of the earth formed part of the atmosphere. It has

[1] Sir Lowthian Bell: Journal of the Iron and Steel Institute, No. 11, 1881.

been calculated that the pressure on the earth's surface was 327 times that at present exerted,[1] and, therefore, much water-vapour must have been forced into the liquid rock-mass. If the principle of occlusion is confirmed, then the molten magma must have been able to take in far greater quantities than that which would be due simply to pressure.

However this may be, away went the moon into space, and immediately both the enormous pressure of the earth's atmosphere was removed and the mass was cooled below the expulsion point. The surface of the moon then became subjected to enormous volcanic activity, sufficiently violent, as some have imagined,[2] to throw out materials beyond the attraction of itself, and which are only now occasionally falling on our earth in the form of meteorites. What became of the water-vapour? If large quantities of water are contained in molten rock, as much, for instance, as comes out in the eruptions of Vesuvius, would there not be some trace of water on the moon, seeing that practically the whole of the surface is one vast field of volcanoes? One can account for much by the evaporation into space and attraction by the earth, but an entire hydrosphere to disappear and leave no traces behind seems impossible. On the other hand, if we imagine that the moon only took away a small amount of water occluded in the molten rock, then we have a quantity which can be more reasonably treated in this way. The form of the lunar volcanoes approaches that of the quiet caldera-form of which Kilauea is the type on earth, but we cannot attach much weight to an argument based on mountains that one can only see and which we cannot ascend hammer in hand.

I am painfully aware of the weakness of much of my reasoning, but most of this is due to the want of knowledge of the fundamental facts of earth-structure. The stresses and strains in a ship of war are known in the smallest detail, but those existing on the earth are little known, although the comparative times during which the two have been under observation are monstrously disproportionate. If geologists could start from the beginning with a certain knowledge that the earth cooled from the centre, and that the whole is in isostatic equilibrium, it would not be possible to be in doubt on such a subject as hot springs; but are not these two facts, as I might almost call them, still in dispute?

If we descend to the bottom of a mine on the Rand one is astonished at the coolness of the workings, as compared with what would naturally be expected from the rate of increase of underground temperature that is usually assumed, that is, 1° F. for every 50 or 60 feet; and it is a well-established fact that in many mineral countries, like Minas Geraes in Brazil, the rate of increase is very small. A study of the British Association Reports on underground temperature leaves one with a sense of despair: how are such divergent results to be sorted out and explained? If one is to regard the earth as a rigid structure,

[1] Rev. O. Fisher: "Physics of the Earth's Crust," 1899, p. 148.
[2] Sollas: Pres. Address, British Association, Bradford, 1900.

I have always thought an explanation impossible, but accepting the principle of isostacy, the whole matter appears simple and the irregularities such as would necessarily be produced. For, regarding the earth as a body that will respond to the smallest stress, provided that it lasts long enough to make itself felt, we see a natural cause for constant differential movement in the outer layers of the globe. Rock is carried from the mountains and deposited in the sea as sediment, ice weighs down the Poles, and even the waters of the ocean in the ages seem to heap up at different places and produce an additional weight on the crust. The differential movements caused by this accommodation to varying stresses leads to the formation of folds and faults; and while these are developing, some of the motion is translated into a certain amount of heat. This has been for many years our stock explanation of the origin of the heat in the hot springs of the Colony, which occur for the larger part in the folded mountain ranges, and I do not see any vital impediment to pushing this principle somewhat further in order to explain volcanic action as the result of earth-movements.

In my recent survey of the Division of Willowmore I found evidence of large movements which had affected the rocks near the surface of the ground. The movement was a tearing one in two directions, north and south, and east and west, and followed certain lines which were separated by a considerable distance; where the two sets crossed each other some very wonderful effects were produced, the most remarkable being the brecciation of enormous masses of quartzite belonging to the Table Mountain Series. In one instance, at Land Kraal, in Baviaan's Kloof, there was in sight a mass of this crush-breccia a cubic mile in extent, but how much more of it was underground it was impossible to estimate. The rock was in places coarsely brecciated, in others ground to fine rock-powder like pounded glass; it was either quite loose and friable, or cemented together with silica or iron compounds.[1] One cubic inch of such a rock in the fresh state requires a load of twenty tons to crush it up, but I am utterly unable to form an idea of the force requisite to crush up even the amount that one could see and measure at Land Kraal; it must have been stupendous. This case is very much more wonderful than any amount of contortion, because the latter is aided by solution, and a very moderate temperature and pressure will suffice to bend up the most resistant rock, provided that it is allowed to remain under their influence for a sufficient length of time. Had this enormous force been concentrated over a less extensive area, and had the rock contained a flux or been composed of a less resistant material than quartzite, there is little doubt that the brecciation would have been converted into fusion and a volcano would have been formed. The distribution of the volcanoes, too, under this mode of origin would have closely imitated that which we find in some actual volcanic areas, the

[1] These crush-breccias will be described in the forthcoming Annual Report of the Geological Commission, Cape Town, 1904.

Galapagos Islands for instance, in which the principal craters lie on points where two sets of fissures cross each other.[1]

The idea that lavas are remelted portions of the crust is an old one,[2] but seems to have been abandoned for the assumption that volcanoes bring up to the surface material that has never been there before, or at any rate since the crust became solid. A re-discussion of the whole of the phenomena of volcanoes on the principles of isostacy seems urgently called for, if only to settle the following questions:—(1) Why do not volcanoes bring up the heavy metals from the interior? (2) Why is the temperature increase measured in stable areas like the Witwatersrand, which would seem to indicate the normal increase, enormously exceeded in some areas, if these are not heated up by differential movements of the crust? (3) Why cannot a force that is sufficient to crumble up a resistant, infusible rock like quartzite, melt one which is fusible and produce a volcano?

The bearing of these speculations on the question of hot springs is to endeavour to show that there is some reason for the explanation that I have been giving for the origin of their heat; for if it be found that volcanoes do not get their material from the primordial magma, then the question of original water will be ruled out. What water the lavas do contain will on this hypothesis be simply that which was once held up in its interstices when solid, with the addition of any that the breaking of the rocks may bring them into communication with.

In this connection it is interesting to notice what very large underground conduits must exist which discharge their waters in the bottom of the sea. We have very few large springs in the Colony, the largest being that at Uitenhage; there are, however, large tracts of country similarly situated in respect to their geology, superficial area, and rainfall, which do not contain anything like so large an output of spring-water. Boreholes also are continually tapping large sources of water without lessening the flow of neighbouring springs, and it seems certain, though difficult of perfect demonstration, that a large part of the water that sinks underground does find an outlet in the bottom of the sea. On the coast we have several fountains that emerge below high-water mark; for instance, all along the sandy coast east of Cape Agulhas. An inverse case occurs also at Eastbourne in England, where an increased pumping from wells situated a mile from the sea brought the salt-water soaking through the greensand.[3] In the Colony, however, we do not have to deal with porous rocks; all underground seepage, outside the infinitesimally slow one through the substance of the rock, takes place through fissures. Conceive now a system of

[1] See C. Darwin, "Observations on Volcanic Islands," in "Geological Observations," 1851, p. 116; and also "More Letters of C. Darwin," 1903, vol. ii, p. 143.

[2] C. E. Dutton: "High Plateaus of Utah," 1880, p. 125.

[3] It would be interesting to know in this connection whether increased pumping from the boreholes that were put down in granite near the sea along the Swedish coast would bring the salt water through the crevices. See C. R. Markham: Geogr. Journ., vol. x (1897), p. 465.

fissures through which, on the one hand, the underground water of a continent passed downwards; and on the other, a system beneath the sea connecting with the first, in which at one time fresh water, at another salt water, infiltrated, according to the mutual pressure exerted by each. Then imagine a differential movement in the crust: the land fissures would be disconnected, and the sea-water would press downwards along the established lines of flow until stopped by the rock in the zone of the movement which had become melted by pressure and friction. This crude explanation would account for the water in lavas, and for their occasional high content in sodium-chloride, that is to say, each volcanic line in which the rock was melted up by earth-movements, if near the sea, would be enclosed on either side by a system of fissures which had long been the conduits for considerable bodies of water, on the one side sending down fresh, on the other salt water. One would think that if this was actually the case, the water once reaching the molten rock would be instantly returned along the way it came in the form of superheated steam. But underground fissures are intricate; they wind upwards and downwards, and the water usually percolates by a system of syphons which will work one way but not the other. Capillarity also comes into play, and, as Daubrée has shown,[1] this works only one way, namely, towards the hotter portion of the rock that contains the capillary interstices. Thus we have the water forced into the zone of molten material, and what little can escape does so in the form of hot springs.

The final result of this line of reasoning is that the water that was pressed into the molten surface of the globe by an atmosphere consisting of the whole of the present hydrosphere is still there, and cannot escape, because, apart from the still doubtful occlusion of the water, this primordial magma is so covered with later deposits that it never has an opportunity of coming to the surface and cooling itself sufficiently to allow the water-vapour to escape. We must look to the veins of quartz, filled with the heavy metals like gold, for the evidences of the very slight extravasation of this primordial water in bygone ages, and we must suppose that deep beneath the surface, far below the zone from which the volcanoes derive their material, such extravasation is now going on, but that it can never be felt at the present surface of the globe. The gold-bearing hot springs of Nevada may be regarded either as an exceptional case of the primordial water having come into connection with the surface system of water supply, or, what is more probable, that the hot springs traverse a mineralized area in which the precious metal had already been deposited, and from which the water has leached out its unaccustomed burden. The reason for considering the latter the more probable is that it seems to me that if the water is the primordial vapour condensed, the heat at which it exists in the interior is a function of the depth, and by coming to the surface it would pass through layers each of which would be heated according to its depth; the water would therefore arrive above ground at the

[1] "Géologie Expérimentale," 1879, p. 258.

temperature of the surface-rocks, and not in a heated condition at all; but if it is water that has soaked in originally from the surface, and has got into the neighbourhood of deep displacements of the rock-crust, then we have a source of energy that is capable of being dissipated to draw upon for our supply of heat, and hydrostatic pressure to bring it back to the surface. We have not been forgetful of the presence of radium in the waters and deposits from hot springs, but as yet there are no results to communicate from South Africa.

IV.—Notes from the Geological Laboratory of Birmingham University. On a Convenient and Simple Method of making Geological Models.

By T. Stacey Wilson, M.D., B.Sc., F.G.S.

MANY ingenious methods and materials have been used for the making of geological models, to show the internal structure and outcrop of a stratified sequence, to furnish maps and lines of section, and to indicate the direction and effects of faults.

Such materials and methods as those of Mr. Sopwith, while most instructive and interesting, are powerless to deal with problems of curved strata, and no material has yet been found by which satisfactory stratigraphical models can be made of folded districts. Such a material must have several properties:—

1. It must be easily made into large plastic sheets of even thickness and of distinguishable colour.

2. It must bend readily and adapt itself sweetly to any surface to which it may be applied.

3. Successive layers must adhere together fairly quickly and quite firmly.

4. The material should set into a rigid but not brittle mass in the end, and yet not be too hard, so that it can be carved readily, or if necessary moulded into any required shape.

5. It would be an advantage if it was cheap.

Casting about for such a substance I have found one which satisfies a good many of these requirements. Not only does it allow of the building up of models out of definite stratigraphical elements in exact imitation of the natural geological structure, but it may possibly be of use in solving certain obscure structural problems. It is also likely to be of considerable use to teachers and students, as models can be built up by or before a class, and it may even have some applications outside geology itself.

The material used is *felt* of various colours, steeped in *melted paraffin wax* that has a melting-point of about 110° F.

The solid paraffin is melted slowly over a spirit-lamp or, better, in a jacketed saucepan or water-bath. Layers of felt are soaked in the melted paraffin and then squeezed fairly dry. The low melting-point allows of this being done by hand. Layers of coloured cloth may be used for thinner beds.

The layers are then superposed one on another to the desired thickness. They adhere together, and the composite mass may be cut with a knife to any shape required. The best tools for further

shaping are gouges and chisels, and for the smaller work a sharp penknife, the material having the consistency of rather hard cheese.

On account of the ease with which the waxed felt can be cut the surface of a model can be carved into a much better representation of the relief of a country than is the case with wood or other materials, and outcrops can be rendered in a much less conventional manner than hitherto.

Faulting can be shown by cutting the model clean through along any given line and joining the severed edges together after heating them slightly; they reunite with the utmost ease into a solid block, which can be carved into shape as before.

Folding may be produced in two ways. Either the complete thickness of several layers may be kept warm and bent as a whole into the desired shape; or else, and this is always necessary when complicated folding has to be rendered, a basal model of the fold types may be carved in wood or cast in plaster, and the waxed felt laid on it and fitted in layer by layer. The surface is, of course, worked up afterwards with the knife or gouge.

Obviously the faults of folds and faults, unconformity, and thrusting can be readily dealt with on the same lines.

A modification of the method must be employed in cases where it is important to deal with beds of varying thickness or those which thin out altogether. This method is also of great use in treating a complicated country such as that to be immediately referred to. For this purpose wool-clippings from a carpet factory, or ordinary felt scraps cut up and teased out, are folded in muslin, soaked in melted paraffin, squeezed out, and then spread out into a layer of the requisite thickness, pins having been previously driven into the base on which one is working, of a height corresponding to the thickness of the stratum. Sculpture is carried out as before.

In order to show the application of this process to the modelling of a particular district it will be most convenient to describe the actual making of a model which I made in 1901 to illustrate a paper on the Harlech district by Professor Lapworth and myself, read before the Geological Section of the Birmingham Natural History and Philosophical Society, March 28th, 1900.

1. The lowest bed on the series dealt with was taken as the floor of the district, and the depth of its base below a convenient plane or base-level (parallel to the sea-level) was calculated at a sufficient number of points in the map to permit of the drawing of contour-lines on the bed so as to give the general character of the folding and faulting.

2. A vertical scale was chosen and contour-lines showing a depth of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ inch, etc., below base-level were drawn on the surface of a block of wood.

3. This surface being taken as the base-level, holes were bored with a bradawl along the contour-lines to depths of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ inch and so on.

4. With a gouge and chisel the surface of the block was now cut down to the bottom of the holes, as is done by a sculptor in roughing out his marble.

Thus a model of the floor of the district is obtained with the gentle rise and fall of its folds and the abrupt drop of its faults.

It is quite evident that a similar base might be built up with cardboard or wax sheets, or modelled in clay, or cast in plaster, or obtained in a less laborious way than the carving of a wood block. The only essentials are rigidity and accuracy.

5. On this carved surface the successive geological formations were built up to scale by means of layers of differently coloured paraffin wax or waxed felt of the proper thickness.

6. In order to ensure the first layer being of the proper thickness the following method is employed. Pins with small heads (entomological pins) a little longer than the thickness of the stratum (or cut to the requisite length) were driven in all over the wooden base. A convenient way of securing the right height was to take a strong metal pencil-case, remove the lead, and draw back the stop till the lead chamber was just the required depth. On inserting the pins' heads into the lead chamber the pencil-case was used to drive the pins in exactly the right distance with the minimum expenditure of time and trouble.

7. The wood is next thoroughly wetted to prevent the paraffin sticking to it, or it may be covered with wet tissue paper, and the coloured wax is spread over the model to the level of the pin heads. Small strips of wet stiff paper or pieces of tin should be inserted along the fault planes so as to give sharpness to the edges of the strata there.

8. As soon as the first layer sets the pins are removed and more pins inserted in the same way to give the thickness of the next stratum of coloured wax. To strengthen the model some of the layers should be put on with waxed cloth or felt in sheets, but this, though desirable, is not absolutely necessary.

9. Where a bed crops out on the surface the coloured wax is carried a little beyond the area occupied by the bed, as shown on the geological map.

10. When all the layers have been put on and have set fairly firm the surface is modelled with the gouge and penknife so as to show the hills and valleys. If this could be done quite accurately, and if the structure and thicknesses were quite correctly rendered, it is evident that the surface of the model should exactly correspond with the country. In practice, however, both the known contour of the country and the known outcrops of the beds are utilised for making the surface of the model approximately accurate.

Before beginning the modelling of the base of a country it is best to indicate by long pins the position of the chief landmarks in the area dealt with. These can be maintained in position as guides throughout the whole process, and removed when the model is finished.

Slight modifications of this process which might easily be devised will obviously render it applicable to problems related to intrusive and volcanic rocks.

V.—The Average Composition of the Igneous Rocks.[1]

By F. P. Mennell, F.G.S., Curator of the Rhodesia Museum, Bulawayo.

THE average composition of the igneous rocks is a point of considerable interest in its relation to the problem of their differentiation, and several attempts have been made to solve it by the collation of analyses. Thus, Mr. Clarke estimated the American rocks to average 59·77 per cent. of silica (which may be taken as representative), and Mr. Harker came to very similar conclusions as regards the British rocks, obtaining 58·46 as his figure. The process followed was to add up the results of all the obtainable analyses and take their mean. If each class of rock analysed occupied the same average amount of space—if, for example, the basic intrusions were approximately equal in bulk to the acid ones—such a process would give results of considerable value. As it is, however, very little consideration will show that unless due weight is attached to the relative abundance of the different classes, the results will be very far removed from the truth. Even in Britain, where the development of igneous rocks is comparatively insignificant compared to the sedimentary ones, there are quite enough exposures of the different types to demonstrate this fact. If a geologically coloured map be examined, and the nature of the various patches of igneous rock be enquired into, the immense preponderance of granite becomes obvious, even though the basaltic lavas make a great show on account of their horizontal extension. In fact, the Dartmoor granite mass, if it be assumed to extend to a depth of only one mile, would probably suffice to weigh down the scale against all the other non-granitic igneous rocks combined. Yet, on the method indicated above, the smallest dyke would be of something approaching equal account, even if a number of analyses of the Dartmoor rock were included.

In other parts of the world where igneous rocks are far more largely developed than in England, the predominance of granites is even more striking. In Africa and Australia there are many single granite masses which are exposed at the surface over areas of not only hundreds but thousands of square miles. The Matopo granite mass of Rhodesia, forming the hills now famous as the burial-place of Mr. Rhodes, covers a horseshoe-shaped tract of country certainly not less than 5,000 square miles in extent; in fact, it may be two or three times as much, as only its northern and north-eastern limits are yet known with certainty. And this is only one of many; in fact, out of the 250,000 square miles covered by Southern Rhodesia and the adjacent territories, it is certainly safe to say that 100,000 are granite, while there is scarcely any other class of igneous rock with even a single outcrop large enough to be visible if inserted in its true proportions on an ordinary map.

The district immediately surrounding Bulawayo may be taken as representative. I have mapped, in the course of nearly two years' work, an area of 2,000 square miles with as near an approach to

[1] Read at the Southport Meeting of the British Association.

accuracy as can well be attained with the present imperfect topographical maps. By dividing the map into small squares an estimate is readily made of the areas covered by the different rocks, with the following result:—

	Square miles.
Sandstones, probably Tertiary (including some lava-flows) ...	215
Metamorphic rocks	730
Plutonic igneous rocks	1,055
	2,000

It will be seen that the plutonic rocks outbalance all the other rocks put together. They comprise portions of four masses, of which one is chiefly syenite (with 63 per cent. of silica) covering 15 square miles. The others, with a combined area of 1,040 square miles, are granite with a silica percentage probably averaging about 70 per cent. It must not be thought that basic rocks are absent; they are, on the contrary, well represented by numerous dykes of dolerite and basaltic flows. We shall, however, be making a generous allowance for them if we suppose there are 1,000 dykes a mile long and five feet wide, with 10 square miles of basalt 20 feet thick. We will further suppose that these rocks contain about 50 per cent. of silica. There are a few intrusions of porphyrite and orthophyre, but they are of little importance and may be reckoned as allowed for amongst the dolerites.

Now let us see what results these figures lead to. We will assume that each dyke and plutonic mass extends vertically to sea-level, that is to say, goes down about a mile. (Bulawayo stands at an elevation of 4,500 feet above the sea, and much of the district is higher.) We have therefore:—

Rock.	SiO_2 per cent.	Area, 69 miles.	Depth.	Volume, cubic miles.
Granite ...	70 ...	1,040 ...	1 mile ...	1,040
Syenite ...	63 ...	15 ...	1 mile ...	15
Basalt ...	50 ...	10 ...	20 feet } ...	1
Dolerite ...	50 ...	nearly 1 ...	1 mile }	
			Total	1,056

Multiplying each silica percentage by the volume of the respective rock, adding up the products and dividing by the total volume, we obtain an average of 69·88 for the whole. Whatever composition is assigned to the granites, the general average will, in fact, approach it within a few parts per thousand. We thus arrive at the conclusion that if all the other rocks of the area were to be fused into the granite masses the difference they would make would be quite imperceptible lithologically, and scarcely noticeable in a chemical analysis. Such a result would, I believe, hold good for the entire African continent and certainly for the whole of Rhodesia. There is nothing to indicate that a different conclusion would be reached in any other extensive area where the plutonic rocks are adequately represented, and there is accordingly reason to believe that granite substantially represents the magma from which even the most basic rocks have been developed by some process of differentiation.

VI.—The Salt Deposits of Dax and the Pyrenees.

By P. W. Stuart-Menteath, Assoc. R. S. Mines.

ON the rail to Biarritz the roots of the Pyrenees first appear at Dax, and are accompanied by those ophites and thermal springs which are special features of the entire chain. Vast deposits of salt, to whose first development I contributed, have added an important industry to the resources of this ancient capital of *Aquæ Tarbellicæ*, where the exact harness depicted on Roman medals is still characteristic of every cart. Beneath the existing ditch of the Roman fortifications rock-salt was accidentally discovered by a boring for mineral water, and the salt is now worked at three miles to the south-east, and is indicated by springs for a distance of seven miles. The deposit is known to be about 100 feet in thickness, but is of unknown depth beneath the existing borings.

Along the entire outskirts of both sides of the Pyrenees similar salt deposits abound, and they are often similarly accompanied by igneous rocks.

The salt formation of Dax is distinctly limited by the valley of the Adour, which here ceases to wander among the sands of the plain, and is suddenly and sharply diverted along a tectonic depression, running towards the Pyrenees in a south-west direction. Precisely parallel to this course, in the Cretaceous and Tertiary rocks of the Pyrenees, there runs, at a dozen miles to the north-west, the most remarkable example known of a tectonic valley sunk beneath the ocean. The Gouf de Capbreton, sinking with steep sides to over 3,000 feet beneath the even bottom of the Atlantic skirt, and affording evidence of igneous rocks in its surroundings and in the irregularities of its floor, is a perfect analogue of the neighbouring tectonic portion of the Adour. One is disposed to attribute the salt deposits of the Pyrenees to an episode in the past history of such valleys, whereby they were upraised, with salt lagoons in their irregular hollows, and with rapid evaporation of the brine by volcanoes such as accompany salt lakes of Eastern Africa. The disposition of Pyrenean salt accords fairly with such a theory; but matters of engineering importance are not usually decided by any royal road of first impressions, however plausible or fascinating.

Still more important than the salt of Dax are those thermal springs which, along ten miles of the tectonic valley of the Adour, form a western limit to the salt by an emanation of over 5,000 tons daily of mineral water at a temperature of 147° Fahrenheit. This water, by impregnating the mud of the Adour, excites a growth of *confervæ*, diatoms, and other organisms, that may develop to even half the weight of the whole material. They transform the complex mass, with production of nascent oxygen from the carbonic acid that accompanies the abundant nitrogen which bubbles from the springs. Such actions, as explained by Bischof, doubtless originate the powerful therapeutic action of the Dax mud baths. One may attribute to such mud the variegated marls which accompany the salt deposits and

which closely resemble those of the Trias formation. A classical investigation of the Iceland springs, by Bunsen, proves that such variegated marls are in active production beside volcanic rocks at the present day. And beside the Baignots establishment at Dax a limestone containing fossils of the Upper Chalk is transformed to dolomite and traversed by the hot springs. But although the springs can furnish by their constituents and effects a satisfactory explanation of both the salt and all its accompaniments of Triassic *facies*, it would be rash to ignore the splendid investigations of Ochsenius on the relations of sea-water to salt deposits throughout the world. Wherever and whenever I have heard the Triassic theory of Pyrenean salt expounded by its foremost representatives, they have ignored such helpful assistance. It is therefore useless to urge their attention to the fact that either the origin from springs or the origin from sea-water can equally be advanced as alternatives to the arbitrary assumption of wedges of Trias introduced by paradoxical contortions that are demonstrably absent in many cases with which they deal.

The thermal springs of the Pyrenees were long since analyzed by Filhol, and their accompanying rocks patiently interpreted by Leymerie. These eminent observers, in 1866, showed me a carbonaceous meteorite whose fall was witnessed, and whose fragments are preserved in the Museum of Toulouse. They furnished me with specimens of its material, and assured me that a portion of its substance had yielded the formula of *humus*. Filhol explicitly remarked to me that it apparently carried vestiges of the life of the original body to which it belonged. I had previously suggested to fellow-students the convenient theory of meteoric origin for every residual difficulty of geology in general. Personally invented theories are thus often crystallized by a fascinatingly confirmatory apparent fact. The practical geologist notes and discards such suggestions in every excursion. Of course, it was practically impossible to ascertain whether the organic matter was originally present or was introduced in the hot meteorite from the soil into which it penetrated deeply when it fell.

I have found the main problems of the Pyrenees to be conveniently represented at Dax. The abundant fossils of the Tertiary plain here meet the similarly abundant fossils of the outermost Cretaceous, so that the relative dispositions are defined by independent evidence of every kind. Desiring to leave something for later observers, I would nevertheless remark that the problems are even here less easily and rapidly solvable than recent innovators have found them to be at points where none of the means of solution available at Dax have troubled the even course of their decisions.

Hitherto the entire work of the observers most familiar with the Dax district has shown that the apparently Triassic marls and salt are independent of any special horizon of the Cretaceous fundamental rocks, and it has proved equally impossible to identify them with any special horizon of the Tertiary. It is only certain that they closely accompany the igneous ophites (diabase or dolerite), and that

they are arranged on lines that exhibit remarkable independence towards the general disposition of the visible rocks. The salt deposits of the neighbouring portion of the Pyrenees exhibit a similar independence, and the latest theory—that they are shovelled from the mountains by vast processes of superficial *charriage*—is a recognition of the general result of observation thus admitted. It coincides practically with the view of Dufrenoy, of anomalous and eruptive origin, for which I have long vainly claimed respect.

But in the treatment of salt deposits it is impracticable to rely on those details of arrangement which are regularly advanced as conclusive by representatives of the new theoretical geology. Every mining engineer is aware that salt is practically plastic and is in nearly every salt-mine subject to contortion by hydration of anhydrite as well as by squeezing. In such recognition of experience the observations of practical engineers, such as Crouzet and De Freycinet, are valuable at Dax, while much other evidence is obviously out of court. The doctrine that the upper gypsum of a salt-mine must be due to a different sea, and therefore to a different formation, because sea-water deposits gypsum first and salt last when boiled down in a pot, was gravely expounded at Cardona by a foremost creator of the *charriage* theory in the Pyrenees and elsewhere; but such views merely exhibit ignorance of the elements of the problem as revealed by Bischof, Bunsen, Ochsenius, etc. Crouzet and De Freycinet plausibly argued that the salt was bedded between horizons about the junction of the Cretaceous and Tertiary as known in their day. Subsequent observation tends to prove that it frequently fills hollows on the surface of the Cretaceous and beneath the Tertiary, the latter being of any age from the Lower Eocene to the Upper Miocene, and probably even to Recent, according to the local circumstances of its deposition above the salt. Of course, no practical geologist would affirm that Triassic salt may not also exist. I have found it existing as the cause of salt springs at Camou, Arrigorriaga, and other places. But the actual Trias of the Pyrenees is singularly unsuited to the purposes of the theorist, and he consequently compares the Pyrenean beds he would class as such to that of Germany and Lorraine. Yet in these last neither bipyramidal quartz, nor arragonite, nor oligist, nor ophite are cited, and it can hardly be argued that gypsum is peculiar to any special formation.

Such being the general situation of the problem, it should be added that the best exposed and most clearly related salt deposits of the Pyrenees are, along the whole Spanish slope, decisively of Eocene or Oligocene age. The attempts of theorists to deny this at Cardona are conclusive regarding the character of their observations, while at every point they have treated on the French slope they have admittedly urged the contrary of what they to-day propound.

The main difficulty at Dax and elsewhere lies in the thick mantle of marine, fluviatile, and æolian sands which cover the surface of the plain, and, accumulating to even hundreds of feet in thickness, drowns the ancient valleys and extends across the plateaux of the Pyrenean roots. These sands are so obviously undistinguishable in detail, and

so certainly misleading as regards their age at special points, that they have been selected as a favourite quarry of evidences for the existence of Pliocene man. In the Appendix to the French edition of Lyell's "Antiquity of Man" an example is cited from Biarritz as clearly beneath the Pliocene *Sables des Landes*. In thirty pages of the Bul. Soc. Ramond of 1878, together with a section of unusual detail, I proved that the remains in question were from modern peat, and later than beds which have since supplied me with a tooth of *Elephas primigenius*. At both Biarritz and throughout the Landes, the sand classed as Pliocene is separated from the underlying Tertiary and Glacial Diluvium by a remarkable Brick-clay, similar to that of Portobello, near Edinburgh. This clay is described as strangely anomalous in position, because it always appears to overlie the Sables des Landes, for the simple reason that it *does* overlie them, as amply proved by local observers. At Biarritz it caps the hill beside the Negresse Station, while the coarse Glacial Diluvium lies beneath it to the margin of the Negresse lake. Blown sands above this supposed Tertiary have furnished the human remains of Biarritz and Dax, whose real age is consequently indeterminate, but trifling. My conclusions were stigmatized as lamentable, but my facts have remained unquestioned, and the Pliocene man in question is regularly cited like his colleague of the Lisbon Congress, who was condemned as spurious both at Lisbon and at Paris by the judges specially selected to report upon the facts. In the Bull. Soc. Géol. of 1896 I have further dealt with the Sables des Landes, and I was in agreement on the point with the regretted Munier-Chalmas. Their Pleistocene age is admitted in the last edition of De Lapparent's treatise.

For further details I must refer to the first volume of the "Mémoires pour servir à l'explication de la Carte Géologique détaillée de la France" (1903), published by the Ministère des Travaux Publics, in which ample references to my original papers, and a tabulation of the fossils of the Pyrenean Trias which finally rewarded persistent search, are conveniently arranged for every scientific library.

In the first place, I succeeded in finding beside the salt-mines of Villefranche (near Biarritz) abundant and unsuspected deposits of the fossils previously classed as Neocomian, and which are now admitted to represent the base of the Upper Cretaceous of the Pyrenees. This formation further supplied me, south of Irun, with sixteen species of Cephalopoda of the Cretaceous horizon of *Ammonites inflatus*, comparable to that of Portugal, and in the middle of rocks mapped as Trias. In all the Western Pyrenees this formation rests unconformably on all previous rocks, and is in direct contact with the Trias, Jurassic, etc., by a bitumen or lignite horizon representing an ancient land or coast surface. To this bituminous horizon one can attribute the important bitumen of Bastennes, near Dax, which was formerly worked by an English company to supply the earliest Parisian asphalt, and is largely described in Ure's Dictionary. It flowed into Tertiary beds in the neighbourhood of an ophitic intrusion, and supplies beautiful moulds of the Tertiary

fossils in black asphalt, in great abundance beside the ruins of the old workings at Bastennes. At Tercis, near Dax, the same horizon of abundant Greensand fossils forms the lowest visible beds above the variegated marls which contain ophite, salt, and gypsum. But *from beneath* these variegated marls there outcrops, at Le Hour, at a trifling distance to the south-west of the salt-mine, a thick band of dolomitic limestone and breccias, alternating with beds of ash, and pinched between extensive outcrops of ophite. This limestone is absolutely identical with the Muschelkalk, which I have found fossiliferous from St. Michel to Ascain, along many miles of the nearest Pyrenees. It is strangely identical with the most typical Muschelkalk of the Hartz, it presents both the peculiar dolomitic breccias and the blue and green *Aerinite* which characterize Triassic beds accompanying ophite at Camarasa in Catalonia, and it abounds in moulds of Gastropods, etc., such as peculiarly characterize the Muschelkalk of the Pyrenees. In a former paper I denied this identity, because the most characteristic portions of the rock had been largely removed by quarrying; but having found them by repeated later visits, I can recognize the identity in both character and relative situation of this typical Muschelkalk. This rock was found to be fossiliferous by Crouzet and De Freycinet, and its fossils classed as Tertiary; Raulin and others classed it as Cretaceous; Jacquot compared it to the Muschelkalk in 1888; M. Seunes declared its fossils to be of the infra-Lias in 1890. As both at Le Hour, Ascain, and many other localities, it is beneath a considerable thickness of Keuper marls, and as the fossils habitually resemble those of the Muschelkalk, the last-mentioned determination is inadmissible and misleading. The real infra-Lias, with *Estheria minuta*, fish spines, and other remains, I have found at Elduayen, Villabona, etc., and it is different in appearance, as well as closely connected with the Lias, containing *Gryphæa arcuata* at Narvarte in the Bastan.

At Dax we have consequently the Trias with salt, gypsum, etc., rising in ridges and bosses from beneath all later rocks, and these outcrops are occasioned by the presence of igneous intrusions that have given rise to abundant thermal springs charged with salt. Obviously this machinery can transfer the salt and gypsum to any depressions or lagoons formed even to the present day, and we have consequently a sheet of salt and gypsum laid down in the extensive depression which borders the tectonic valley of the Adour. This sheet appears to date from the latest vicissitudes of the district, and certainly from later than the last upheaval of the Pyrenees. Wherever we find similar machinery of Triassic bosses below, igneous intrusions breaking and dislocating that Trias, springs conveying its contents to the surface, and tectonic irregularities and barriers occasioned by the movements of the Pyrenees, we may naturally find salt deposits of any age later than the Trias. The detection of their presence, and the estimation of their depth and extent, is a problem special to each particular district, and depending on the entire geological history which can be worked out on the spot.

The vast sheets of gypsum and salt that extend from Olot to

Logroño along the Spanish side of the Pyrenees are clearly deposited from evaporated lagoons formed during the uprise of the chain in Tertiary times. The salt deposits of the French Pyrenees are of a more local and varied character. There is a general contrast between the two series which reflects the general contrast between other features of the two slopes. In the salt deposits of the Pyrenees one finds every variety of lagunar character on the Spanish side, and every variety of tectonic and local character on the French side. Among the French deposits one may trace actual craters of explosion filled with salt, old valleys filled with spring deposits, and small accidental hollows that have preserved patches of salt water in rising from the sea. Sunk valleys, like the Gouf de Capbreton, have naturally preserved sunk deposits, when buried beneath Tertiary accumulations; and the ancient surfaces of the Cretaceous formation and of the Oligocene land are naturally marked by such vestiges of their irregular uprise from the sea—especially where the innumerable igneous bosses, that have visibly traversed the Upper Cretaceous of the Pyrenees, have roughened the surface and given rise to later fracture and irregular denudation. As salt and gypsum can only resist solution under peculiarly favourable circumstances, it is certain that such solution must have produced extensive dislocation. In the mountains of Persia and South America, gypsum is over 1,000 feet in thickness across distances of over 50 miles. No borings have yet fathomed the salt and gypsum of the Pyrenees, although 1,082 feet has been reached at Salies du Salat without signs of change. Such facts are a mere suggestion of what observation might yield if not referred to one current theory.

Not only the whole of the varied phenomena in question, but even such local chemical productions of gypsum in the Flysch as are visible near Biarritz at Croix d'Ahetze and elsewhere, have been treated as characteristic of the Trias formation. In the Alps, as in the Pyrenees, the gypseous beds of the Trias have been credited with all the salt and gypsum of later beds of every age. The stratigraphy which results from attempting to unite Oligocene and Triassic beds into one formation is naturally astounding.

Round Biarritz, more conveniently than at Dax, the diversity of the gypseous and red clays classed as Trias by Parisian geologists may be verified. At Laduch, west of Villefranche, the fossiliferous base of the Cretaceous may be seen resting on the gypseous marls of the Villefranche salt-mine. At Caseville similar red clays, with ophite and gypsum, are distinctly intercalated between the fossiliferous Danien and Lower Eocene, and at Fontarabia they are inclined at only 15° to the horizon. Beside the Negresse Station the red brick-clay, of post-Glacial age, is now largely worked, and is above the Glacial Diluvium that descends to the level of the lake, while over it there is nothing but the modern blown sands of the spurious Pliocene man. At Croix d'Ahetze the similar gypsum and clays, formed by decomposition of iron pyrites in the Flysch, thickly cover the almost horizontal surface of a quarried sheet of fucoidal Flysch limestone. All the diverse formations thus enumerated, as

well as superficial red clays formed by decomposition in quarry fissures and ancient drains, have been gravely classed as Trias by the creators of the *charriage* theory in the Pyrenees and the Alps. And it matters nothing that the disposition of the real Trias in the neighbouring mountains is as flatly opposed to their theory as it is possible to imagine.

The presence of the Muschelkalk at Dax and other points of the sub-Pyrenean plain immediately beneath the base of the Cenomanien is curious as evidence of the absence of the entire series between that horizon and the Keuper marls. But in the whole Western Pyrenees I have found these intermediate rocks to be largely represented at one point and entirely absent at another, in the most irregular and closely contrasting fashion. The explanation lies in the extensive transgression of the Cretaceous, which is attested by the lignites that alternate with Gault fossils between Ascain and St. Pe, and at Hernani, Cestona, etc., and which, with abundant *Orbitolina concava*, rest directly on the Trias south of Roncesvalles. Extensive and irregular denudation appears alone to fit the facts. Such denudation implies that the Pyrenean area was, in Lower Cretaceous times, as irregular and mountainous as it is to-day.

The best examples of the Muschelkalk can be seen in the valley of the Bastan above Elizondo, and at Urdax and the basin of St. Jean Pied de Port. It alternates with sheets of ophite that usually overlie it and occupy the place of the Keuper. It is thrown into repeated strips by faults that let down bands of Cenomanien fossiliferous limestone, forming long canal-like intercalations, as in the Alps of Gosau. Both the faults and the ophitic intrusions are consequently of an age later than the Cenomanien. A desire to class the ophites as Triassic, on grounds of micrographic theory, has long hampered the recognition of the facts.

The salt of the Dax mine is arranged in lenticles coinciding in both dip and strike with the Muschelkalk and the ophite which adjoins it. I have found the same coincidence with the ophite in the similar salt mass of Bassussary, near Biarritz, and it has been ascertained in the mine of Villefranche. In the last two cases the disposition is directly across the strike of the Cretaceous rocks, and in the earlier workings at Dax, described by M. Genreau, the disposition was similarly independent of the Cretaceous.

The lesson derivable from the Pyrenean salt-mines is that of the extreme danger of hasty generalization, and of the necessity for studying each particular case as it is studied in the practice of the mining engineer. It affords a striking warning against the facile assumption that old rocks must be superposed by superficial transport from a distance, because apparently insuperable difficulties seem to exclude their intrusion from beneath. The most experienced geologists have, after repeated observation, classed the Dax Muschelkalk as Cretaceous or Tertiary. When that rock is recognized as Triassic it does not follow that it is superposed on later beds. Its relations are merely such as are constantly recognizable within the dislocated and contorted area of the Pyrenees, and these complex

relations can be recognized as extending to Biarritz and to Dax. The latest observations on the Carpathians and the Eastern Alps amply establish the protrusion of the Klippen from beneath, and the latest surveys of Algeria prove that, where the plastic Trias is in question, local and unsuspected intrusion and protrusion have no such limits as are assumed in the theory of *charriage*.

It is more than thirty years since I first discovered the decisive example of Cretaceous gypsum at Croix d'Ahetze. Since then I have found decisive examples of the production of gypsum, in place, in rocks of any age from the Muschelkalk to the Tertiary. Yet in both the Alps and the Pyrenees the assumption that gypseous beds represent the Trias is the selected and regular basis of stratigraphical paradoxes which claim to reverse geology. It has been as easy to ascertain the truth as in the case of the Pliocene man, but no single observer has cared to verify the facts. The latest theory rests upon the assumption that salt and gypsum are of fixed age. It has thus selected for its basis precisely those materials which are, both chemically and mechanically, plastic and transferable to such a degree that any stratigraphical inference founded upon them must be essentially arbitrary. At Dax, Biarritz, and Cardona the opposition between fact and fancy can be recognized.

VII.—The Zoning of the Culm in South Germany.

By Dr. J. H. Parkinson.

"Ueber eine neue Culmfauna von Königsberg unweit Giessen, und ihre Bedeutung für die Gliederung des rheinischen Culm." Von Herrn Harold Parkinson aus Halstead (Essex). Zeitsch. d. deutsch. geol. Ges., Jahrg. 1903, Heft 3, pp. 1–46, pls. xv, xvi.

"On a new Culm Fauna at Königsberg near Giessen, and its significance for the division of the Rhineland Culm."

IT has been suggested to me that a brief résumé of an illustrated article published last year in the *Zeitschrift der deutschen geologischen Gesellschaft* might be of general interest. The article in question embodies a piece of research work undertaken at the instance and under the direction of Professor Kayser, of Marburg, who during the Summer of 1900 observed in the neighbourhood of Königsberg, not far from Giessen, a bed of rock differing palæontologically and petrographically from the surrounding Culm slate. The rock, a slaty breccia with a considerable limestone content, furnished even on cursory examination a fauna deviating considerably from that generally associated with the Culm. Type-fossils of the Posidonia Slates (the "Culm of Herborn"), such as *Posidonia Becheri*, *Orthoceras striolatum*, and *Goniatites crenistria*, were not met with, but on the other hand Crinoid stems together with fragments of large *Producti* and of Trilobites of the genus *Phillipsia* appeared plentiful.

In order to obtain a fuller knowledge of the fauna of this remarkable niveau, Professor Kayser, under whom I was at the

time studying, most kindly handed over to me its further examination; consequently, in the Autumn of 1902, I devoted several weeks to the study of the Culm rocks in the neighbourhood of Königsberg, and especially to the collection of fossil remains from this particular bed. The general composition of the Culm in this locality is similar to that elsewhere in Hessen, that is to say, directly over the late Devonian diabase lies a thin zone of flinty slate, accompanied here and there by small beds of limestone; next above occur the well-known greenish-grey Posidonia slates (as at Herborn); and, still higher, darker slates, much resembling those used for roofing—indeed, about half a mile east of Königsberg they have actually been quarried for this purpose. To these slates belong the fossiliferous beds which form the subject of this article; above them are found the beds usually known as Culm Grauwacke.

Passing at once to the occurrence of the slaty breccia, it should be stated that the beds were recognised in this neighbourhood at two or three distinct spots. At one they lay horizontally among the roofing-slates already mentioned, several outcrops occurring on the side of the roadway connecting Königsberg with the village of Frankenbach. Though I only succeeded in finding *fragments* of organic remains here, this was by no means the case at the second spot, where the breccia-bed occurs under conditions more favourable for observation. Here, directly north of the township, either it forms a small fold, the limbs of which incline gently west and east, and are interrupted by a fault of inconsiderable extent, or, as I am inclined to think more probably the case, we have to do with the outcrops of *two* breccia-beds separated from each other by grauwacke-slates. One is the more inclined to the latter opinion, because the larger outcrop (about 7 yards long and 1½ feet thick) is characterized by a deep brown coloration, due to the presence of iron and manganese compounds, wholly lacking in the smaller, which moreover possesses greater limestone content, less thickness and greater hardness, in these respects resembling the beds already referred to as occurring eastward of this spot; only in the former of these outcrops do fossil remains occur at all abundantly. A third but unfossiliferous bed of the rock was also observed at no great distance.

This slaty breccia is not, however, confined to the neighbourhood of Königsberg. Dr. Drevermann, assistant in the Geological Institute at Marburg, first called my attention to its occurrence near Battenberg on the Eder, about 30 miles north of Königsberg, and there I succeeded in locating five or six outcrops, with, however, only few organic remains, and those in most fragmentary condition.

I had to rely, therefore, chiefly on the material collected at Königsberg, the examination of which was rendered additionally difficult by the fact that the fossils occurred almost always as casts and moulds, and in a most crushed and distorted state. Though much of the material, therefore, was from a palæontological standpoint valueless, I was able to attain to the specific determination of the following forms with tolerable certainty:—

A Comparison of the Culm Fauna of Königsberg with that of the Rhine District, the Harz, and England, also with the Fauna of the Carboniferous Limestone of Belgium.

The Culm Fauna of Königsberg, etc.	Carb. L., Belgium.			Culm of Rhine Schiefergeb.	Culm of Harz and Magdeburg.	Culm of England.
	Etroeungt Beds.	Tournai Beds.	Visé Beds.			
Phillipsia Eichwaldi, Fischer, var. *Hassiaca*, n.var.			*	*		
P. gemmulifera, Phillips			*			
Griffithides seminifer, Phillips			*			
Bellerophon reticulatus, M'Coy			*			
Loxonema cf. *acuminata*, Goldfuss			1			
Pleurotomaria cf. *pisum*, De Kon.			*			
P. cf. *sublævis*, De Kon.			*			
P. cf. *subvittata*, De Kon.			*			
P. blanda, De Kon.			*			
P. cf. *subgranosa*, De Kon.			*			
Conocardium aliforme, Sow.			*			
Aviculopecten, sp. 1						
Aviculopecten, sp. 2						
Scaldia globosa, De Kon.			*			
Nucula gibbosa, Fleming			2			
Macrodus cf. *reticulatus*, M'Coy			*			
M. squamosus, De Kon.			*			
M. multilineus, De Kon.			*			
M. cf. *bistriatus*, Portlock	*		*			
Productus giganteus, Martin			*			
P. punctatus, Martin			*			
P. semireticulatus, Martin		*	*			
P. scabriculus, Martin	*		*			
P. plicatilis, Sow.			*			
P. mesolobus, Phill.		*	*			
P. fimbriatus, Sow.			*			
P. pustulosus, Phill.	*	*	*			
P. costatus, Sow.			*			
P. cf. *cora*		*	*			
P., sp. 2						
Chonetes papilionacea, Phill.			*			
C. Hardrensis, Phill.			* 1	*	*	*
C. Buchiana, De Kon.			*	*		
C. Buchiana, var. *interstriata*, Davidson						
C. cf. *Dalmaniana*, De Kon.			*			
Leptæna rhomboidalis, Wilckens	*	*	*	*		
Orthothetes crenistria, Phill.	*	*	*	*		
O. sp.						
Orthis resupinata, Martin	*	*	*			
O. Michelini, L'Eveillé		*	*			*
Spiriferina insculpta, Phill.		*	*			
Spirifer cf. *trigonalis*, Martin			*			
Athyris squamosa, Phill.		*	*			
A. planosulcata, Phill.		*	*			
A. Royssii, L'Eveillé	*	*				
A. cf. *expansa*, Phill.						
Camarophoria, sp.						
Fenestella plebeja, M'Coy	*		*			
Hemitrypa oculata, M'Coy		*	* 1			
Archæocidaris Regimontana, n.sp.						
Pleurodictyum Decheni anum, Kayser				*		
P. sp.						
Zaphrentis, sp.						
Asterocalamites scrobiculatus, Schloth.				*	*	
Crinoidal remains						
Plant remains						

[1] Occurs in the Waulsort Beds. [2] Mourlon (Géol. de la Belgique, ii. p. 41) mentions the occurrence of this species in Belgium, but does not give the horizon.

The foregoing list contains no single species in common with the Cephalopod Limestone of Erdbach-Breitscheid,[1] universally recognised as the lowest niveau of the Culm in South Germany. Only eight of the enumerated fossils, moreover, have been found in the next succeeding horizon, i.e. in the Posidonia Slates of Herborn and Aprath (among them the English forms *Chonetes Hardrensis, Leptæna rhomboidalis, Orthothethes crenistria, Orthis Michelini*, and *Pleurodictyum Dechenianum*), nor are the best known species of the Posidonia Slates of Germany and of the Culm Measures of England found at Königsberg. We must conclude, therefore, that we have to do with a new fauna of the Culm, so far as these localities are concerned.

Crossing the Rhine, however, we meet with a remarkably corresponding fauna in the Carboniferous Limestone of Belgium. This limestone is now divided into three main horizons, those of Étroeungt (transitional between the Upper Devonian and the Carboniferous), Tournai, and Visé. Only eight Königsberg forms occur in the lowest, 12–13 in the central, but no less than 40 in the uppermost of these; in other words, 83 per cent. of the species found at Königsberg are also met with in the Visé horizon of the Carboniferous Limestone, amongst them many forms which are in Belgium confined to this niveau, such, to name no others, as *Productus giganteus, P. plicatilis, P. punctatus, P. fimbriatus, Chonetes papilionacea*, and *Griffithides seminifer*. We are consequently undoubtedly justified in regarding the slaty breccia of Königsberg as the equivalent of the Visé horizon of the Carboniferous Limestone. This result affords us a means of zoning the Culm on the basis of the division of the Lower Carboniferous in Belgium. In the Rhine district two different Culm faunas have up to the present been recognised, that of Erdbach-Breitscheid and that of Herborn, Aprath, etc. The Cephalopod Limestone of Erdbach-Breitscheid has been shown by Holzapfel to be the equivalent in age of the Étroeungt beds in Belgium, identical or similar *Prolecanites* occurring in both. Recently, too, Dr. Drevermann has described a similar fauna from Ratingen, on the right side of the Rhine. The Marwood and Pilton beds of North Devonshire, which are of transitional character, are possibly also of similar age. Since the Königsberg breccia must be regarded as the equivalent of the Visé horizon, and at the same time lies stratigraphically higher than the Posidonia Slates, the latter must be regarded as approximately corresponding to the beds of Tournai, i.e. to the middle division of the Carboniferous Limestone, and the same must also be true of the Posidonia Slates of the English Culm Measures. We may summarize the results arrived at in the following table:—

Zones of the Culm on the Right Bank of the Rhine.	Zones of the Carboniferous Limestone of Belgium.
3. Slates with the Königsberg breccia.	3. Visé horizon.
2. Posidonia Slates of Herborn, etc.	2. Tournai horizon.
1. Limestone of Erdbach-Breitscheid and basal flinty slate.	1. Étroeungt horizon.

[1] Cf. Holzapfel, "Die cephalopodenführenden Kalke des unteren Carbon von Breitscheid-Erdbach bei Herborn," Dames und Kayser, Paläont. Abt., Bd. v, 1889.

A further consequence of this discovery must be the removal of that very great series of compact conglomeratic Grauwacke-beds so common on the right bank of the Rhine and elsewhere—in Devonshire, for example[1]—from the Culm to the Upper Carboniferous, thus reverting to the view held some years ago by H. von Dechen and R. Ludwig. This follows from the fact of their lying near Battenberg still higher than the Königsberg strata, shown to be the equivalents of the Visé horizon, i.e. of the Upper Carboniferous Limestone, and that the expression 'Culm' can only be employed to express equivalence with the Lower Carboniferous. We must look upon the Grauwackes, containing the well-known flora (*Lepidodendron, Archæocalamites*, etc.), as an equivalent of the Millstone Grit of England and the Flötzleere Sandstein of Westphalia.

It remains only to be added that the originals of the fossils mentioned in this sketch are preserved in the museum of the Geological Institute of the Imperial University at Marburg.

VIII.—Note on the Marbela Manjak Mine, Trinidad.

By R. J. Lechmere Guppy.

I HAVE been favoured by James Wilson, Esq., with samples of material from the Marbela Manjak Mine. They are—

No. 1.	Clay from	No. 1 Gallery,	75	feet deep.
No. 2.	,,	No. 2 ,,	127	,,
No. 3.	,,	foot of shaft,	150	,,
No. 4.	Sand-rock.			

There is no essential difference between Nos. 1, 2, and 3, and No. 4 only differs in being harder, not liable to disintegration by water, and in containing more arenaceous and less argillaceous matter than the other samples. Calcareous matter in all the samples is from 15 to 20 per cent., and consists almost entirely of shells of Foraminifera. There is a considerable amount of sulphur, chiefly as pyrites, greatest perhaps in No. 3, and fragments of Manjak[2] occur in No. 1.

In appearance there is much resemblance between this material and that of the Naparima oceanic beds, though the latter is generally of a lighter colour. But on examination a very considerable difference is found to exist between the two formations. Both are extremely fine-grained substances, indicating deposition in some depth of water. But the proportion of argillaceous and arenaceous matter in the Marbela samples is very much greater than in the oceanic beds. This betokens in the former case the greater nearness of land and the influence of rivers. In the Marbela samples the sandy matter mostly occurs in the form of lumps or irregular small

[1] Ussher: "The Culm Measure Types of Great Britain"; London, 1901.

[2] Manjak is a substance originally found in Barbados. It is geologically coal, but chemically a form of bitumen. It is described in Schomburgk's "History of Barbados," pp. 551, 569; and (as coal) in Proc. Sci. Assoc. Trinidad, 1877, p. 110 (see Guppy on Coal, etc., Proc. Vict. Inst. Trinidad, p. 507).

masses or patches. The Foraminifera are all of species found in the oceanic beds. This might indicate that the deposits were laid down on the ocean border, occupying a position intermediate between the truly oceanic deposits and the shore. The fossils frequently show signs of decay and wear—this is particularly noticeable in the case of *Pulvinulina pauperata*. A very noticeable difference is that the material of the oceanic beds when washed yield a residue consisting almost entirely of Foraminifera (chiefly *Globigerina*), while that of the Marbela deposit consists mostly of small pieces of slaty-looking and ferruginous materials, the foraminiferal fauna being much scantier than that of the oceanic beds, and it shows no relation either to that of the Pointapier beds or to that of Sangregrande.

As the Marbela Mine is in the Nariva Series (see my paper in GEOL. MAG., 1900), this series is possibly newer than the oceanic beds, and was formed during the upheaval of the latter, being partly composed of material derived from the oceanic beds. I admit that this opinion is chiefly conjectural—it is in opposition to that of Messrs. Harrison and Jukes-Browne. The conditions generally of the Marbela deposit would suit a depth of water of 100 fathoms or less, and thus it would appear that the Manjak was deposited or formed on a bottom of that depth. It is easy to conceive that the heavy tropical timber brought down by the rivers might sink to that depth. Moreover, such timber is susceptible of being borne along by currents in the same manner as clastic material generally, and hence we find it in the same region as finely-grained arenaceous and argillaceous deposits derived from the degradation of the continent. This explanation further admits of application to the case of Barbados.

REVIEWS.

I.—MEMOIRS OF THE GEOLOGICAL SURVEY OF THE UNITED KINGDOM.

THE CRETACEOUS ROCKS OF BRITAIN. Vol. III: THE UPPER CHALK OF ENGLAND. By A. J. JUKES-BROWNE, with contributions by WILLIAM HILL. 8vo; pp. x, 566, plate, illustrations. (London, 1904. Price 10*s*.)

THE Geological Survey are to be congratulated on completing their Official Report on the Cretaceous Rocks of England, for with the publication of this third and last volume the results of many years' work have been given to the public. It is to be regretted that an account of the Irish and Scottish Cretaceous rocks was not included. This volume deals with the White Chalk alone, and of the White Chalk the upper portion only. The beds dealt with are defined by the authors as 'Upper' Chalk, and consist of the following zones:—Zone of *Holaster planus*, of *Micraster cor-testudinarium*, of *Micraster cor-anguinum*, of *Marsupites testudinarius*, of *Actinocamax quadratus*, of *Belemnitella mucronata*, and of *Ostrea lunata*. Since the description of the Chalk Rock by W. Whitaker in 1859, the 'Upper' Chalk of the Survey has

generally been defined as all that part of the Chalk which overlies that rock wherever it can be identified. Mr. Whitaker's Chalk Rock, which possesses a typical structure and is characterised by a peculiar fauna, occurs towards the upper part of the *Holaster planus* zone, but in this memoir the whole of this zone is included in the 'Upper' Chalk. Other hard beds, similar in lithological aspect to the Chalk Rock but devoid of the peculiar fauna, occur, especially in the zone of *Terebratulina gracilis* of the Dorset coast. Precise limits to the various zones have been defined in the series of papers recently published by Dr. Rowe, by means of the distribution of the fauna; and generous recognition of the work of that author and his colleague, Mr. Sherborn, has been accorded by the authors themselves, as well as by the Director, Mr. Teall, in his prefatory remarks.

We need therefore merely remark on the new zone of *Ostrea lunata*, which is founded on the admirable paper published by Mr. Brydone, and on the unpublished researches of Mr. Clement Reid, on the Trimingham area in Norfolk. This small but interesting area consists of beds of Chalk, lying upon the strata of the *mucronata*-zone, and characterised by a fauna comparable in many respects with that of the Chalk of Rügen and Maestricht. The occurrence of a small oyster in great profusion has led to the adoption of *Ostrea lunata* as the distinguishing name for the zone. Personal observation, however, would have shown that the oysters occur only in one of the beds.

After defining the various zones the authors discuss the typical fossils, special attention being called to the forms of the genus *Micraster*, whose value, first pointed out by Mr. C. J. A. Meÿer, was fully worked out by Dr. Rowe. Condensed diagnoses of these forms and rough sketches of the ambulacral areas and of the labral plates are supplied.

Chapters iii to xx deal with the description of the beds proper, and contain a vast amount of valuable material concerning the various exposures from Devon to Yorkshire, especially with regard to the inland areas, not yet subjected in many cases to critical zonal division by means of their fossils. It is unfortunate that Dr. Rowe's paper on the Yorkshire coast was not published in time for quotation, the Yorkshire chapter being the poorest in the volume.

A sketch of the "Upper Chalk in France" occupies chapter xxi, and allows of easy comparison with the corresponding beds in England. Some interesting remarks communicated to the authors by M. Grossouvre, who has zoned the Chalk of France with reference to the Cephalopod fauna, are quoted. M. Grossouvre writes: "The classification established by the evolution of the Ammonite-faunas represents, in my opinion, the ideal theoretical classification or standard for comparative purposes, to which all regional classifications should be referred for the purpose of correlating and synchronising the strata of different countries. . . . . On the other hand, for the practical purpose of establishing the stratigraphy of the Cretaceous series of any given country, we shall be obliged to

found it upon the study of the special fauna which the beds contain. Thus, where Micrasters and Echinocorys are the predominant fossils, we must base our zones on the succession of different species of these Echinoderms; elsewhere the Hippurites or other shells may furnish the requisite data. But when the various local or regional classifications have been thus established, and we wish to compare them with one another, then they can be referred to the standard stratigraphical scale which I propose to establish by means of the succession of Ammonite-faunas."

Mr. Hill continues his series of observations on the microscopic structure and components of the Upper Chalk in chapters xxii and xxiii. the lists of Foraminifera being supplied by Frederick Chapman. Mr. Hill finds the microscopic structure of the typical Chalk Rock from Dorset and Wiltshire so characteristic that it is hardly possible to mistake it for chalk from any other horizon. A slice cut from the rocky chalk at the base of the *H. planus*-zone at Pinhay shows all the characteristics of Chalk Rock; and where the Chalk Rock is absent, as in Kent, Surrey, and Sussex, and the zone of *H. planus* consists of rough, lumpy, and nodular chalk, the nodules near the base of the zone present a similar structure to that of the Chalk Rock. On the other hand, the Chalk in which *Holaster planus* has been found in Norfolk, Lincolnshire, and South Yorkshire, differs entirely in structure both from the Chalk Rock and from the nodular chalk of this zone.

The authors find from an examination of the bathymetrical conditions prevailing during the formation of the Upper Chalk that there is distinct evidence of a shallowing of the chalk sea, during the deposition of the *Holaster planus*-zone, succeeded by a gradual deepening which culminated possibly during the deposition of the *Marsupite*-zone, again to be succeeded by a progressive shallowing up to the final passage of the Chalk into the Tertiaries. While not presuming to affix a definite limit to the depth of the sea during *Marsupite* times, the diagram accompanying the Report suggests 700 fathoms as the probable extent of the depression. Dr. Smith Woodward's researches among the fishes of the Chalk have shown that "the majority of the deep-sea fishes of the Cretaceous period are more or less closely related to the Scopeloids and Berycoids, which still form so conspicuous an element in the abyssal fauna." They possess luminous organs.

We are glad to notice that chapter xxv is devoted to "Economic Products of the Chalk," a subject omitted in vol. ii. The officers of the Geological Survey have exceptional opportunities for amassing this kind of information, which is not only of importance to the public but tends to the completeness of their work. We looked in vain in vol. ii for a sketch of the important industry in Portland cement, which occupies so large a business feature in the Medway area, and it is but briefly mentioned in vol. iii.

The "Physical Features of Chalk Districts" forms an interesting chapter, and the "Water Supply from the Chalk," even in so condensed a form, is of great general importance. In this latter

chapter the views of Dr. J. C. Thresh on the "Saline Constituents of Chalk Waters" receive especial attention and criticism. Appendix I contains critical remarks on some species of fossils by Messrs. E. T. Newton and A. J. Jukes-Browne, and a list of fossils from the Chalk of England, compiled from various authors. We do not propose to say anything about these lists beyond asking on whose authority *Uintacrinus westfalicus*, Schlueter, is quoted on pp. 8 and 503. Dr. Rowe in his careful papers has nowhere attached a specific name to this Crinoid, nor has Dr. Bather, in whose hands the bulk of the material has been for years, done so. The matter is still *sub judice*, and those who, without special knowledge and without seeing the material, have definitely identified the English specimens with the form from Westphalia, have incurred the grave responsibility of introducing into our lists yet another name at present meaningless and confusing.

The volume concludes with a Bibliography, in which we are glad to see an old friend, the Rev. J. Townsend, who wrote on Wiltshire in 1813, and who is the special subject of a note as to the interest of his book on p. 193.

This memoir on the Cretaceous rocks of Britain, projected in two volumes, has been concluded in three, and will form a companion to Mr. H. B. Woodward's memoir on the Jurassic rocks. Of the indefatigable energy and trouble taken by the authors we have had abundant evidence, and of the selfless co-operation of their colleagues, still more. We congratulate Mr. Jukes-Browne and Mr. Hill on the completion of their labours, which cannot fail to tend to that progress which is ever continuous in geology.

II.—A Text-book of Geology: intended as an Introduction to the Study of the Rocks and their Contents. By W. Jerome Harrison, F.G.S. 8vo; pp. vii, 350. Fifth edition. (London: Blackie & Son, 1903.)

WE welcome the fifth edition of this handy guide to geology, not simply because it is the work of a painstaking and enthusiastic worker, but because it is a thoroughly reliable introduction to the science. Although the greater part of the work remains as in the last edition (noticed in the Geol. Mag. for 1897, p. 329), revisions of names of fossils and other revisions or additions have been made here and there. In the Appendix there is added a Table showing the range in time of the principal genera of fossil invertebrates. The examination papers in geology comprise some of the later questions set by the Board of Education. The work is one eminently suited to the requirements of those working for examination, though we believe that the halcyon days for students and teachers, for examiners and assistant examiners, under the Board of Education are over!

There are a few slips which might be avoided in a subsequent edition.

P. 15. The Thames does not discharge into the English Channel, but into the North Sea.

P. 274, fig. 2. *Nucleolites dimidiatus*, Phil., a well-known Corallian species, is enumerated amongst the fossils characteristic of the Chalk.

P. 264. Waterhouse-Hawkins' incorrect restoration of *Megalosaurus* might with advantage be replaced by Marsh's figure of *Ceratosaurus*, which was most probably identical with our Jurassic Dinosaur, and was no doubt (judging by its skeleton) *bipedal*, having *very small fore-limbs*, only of use in seizing its prey (see GEOL. MAG., 1896, p. 392, Fig. 3).

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

April 13th, 1904.—J. E. Marr, Sc.D., F.R.S., President, in the Chair. The following communications were read:—

1. "The Discovery of Human Remains under the Stalagmite Floor of Gough's Cavern, near Cheddar." By Henry Nathaniel Davies, Esq., F.G.S.

Gough's Cavern opens at the base of the cliffs on the south side of Cheddar Gorge. Various human and animal remains have been discovered at different times in the clearing out of parts of the main cavern. The principal deposits are a stalagmite-like travertine overlying cave-earth, and the latter at one place encloses a tabular limestone block surrounded with flint chips. During draining operations it was necessary to excavate part of a fissure running northwards out of the vestibule of the cavern, when a human skeleton was found, associated with flakes, scrapers, and borers of flint, embedded in cave-earth, which overlay a lower bed of stalagmite and was overlain by a second bed five inches thick. The skeleton was nearer the top than the bottom of the deposit, and the remains excavated comprise the skull, the bones of an arm, a leg, and part of the pelvic girdle. The other bones were allowed to remain *in situ* and may now be seen. The position of the skeleton was that which would have been assumed by a drowned man. Interment is out of the question because of the narrow and ship-shape of the fissure, which was choked up with undisturbed débris and calcareous deposits. The stature of the man was 5 feet 5 inches; he was of muscular build, with prognathous jaws, a straight thigh, and a thick dolichocephalic skull. The animal remains found in the cave-earth of other parts of the Cavern, and held by the author to be contemporaneous with that in the fissure, are those of mid and late Pleistocene age; and this evidence, together with that from the position of the skeleton, the shape of the cranium, and the form and workmanship of the flakes, points to a period towards the close of the Palæolithic or the opening of the Neolithic age.

2. "History of Volcanic Action in the Phlegræan Fields." By Professor Giuseppe De Lorenzo, of the Royal University of Naples. (Communicated by Sir Archibald Geikie, Sc.D., Sec.R.S., V.P.G.S.)

In an introductory section the author sketches the general geological structure of the district around Naples, and shows the

disposition of the chief lines of fracture by which the Triassic, Cretaceous, and older Tertiary formations were traversed previous to the commencement of volcanic activity in this part of Italy. He recognizes three chief periods in the volcanic history of the district.

I. The eruptions of the first series took place under the sea during the Pleistocene period. Their surviving products can be grouped in two distinct divisions, each recording a different eruptive phase. The older of these (*a*) is represented by the piperno and grey pipernoid tuffs of the Campania, which extend under the broad plain into the valleys of the Apennines. These deposits consist of grey trachytic tuff, with scattered black scoriæ, and with a varying proportion of non-volcanic sediment washed down from the hills. The vents whence they were ejected are now no longer to be traced, as they have been obliterated or covered up by later accumulations. The piperno, well developed at the foot of the hill of Camaldoli, has given rise to some difference of opinion as to its nature and origin. The author is disposed to regard it as a trachytic lava with schlieren, the dark lenticles being made up of such minerals as augite, ægerine, and magnetite, while the lighter matrix is felspathic (anorthose) with a spherulitic structure and microlites of ægerine and augite.

The second phase (*b*) of the first eruptive period is represented by ashes, lapilli, pumice, and sands, intercalated with marine shell-bearing clays and marls, and also with conglomerates and breccias, these coarser kinds of detritus overlying them and varying in thickness according to their proximity to or distance from the vents whence the materials were ejected. The accumulations of this epoch were pierced through in the artesian boring at the Royal Gardens, Naples, where they were 330 feet thick.

II. Above the records of the first volcanic period lie those of the second—the yellow tuff, which forms the most wide-spread and most characteristic of all the volcanic formations of the Phlegræan Fields. It is a yellow or cream-coloured, compact, well-stratified aggregate of trachytic detritus, through which are scattered fragments of tuff and lava. Its average thickness exceeds 300 feet. That it was a submarine accumulation is shown by the occurrence in it of oysters, pectens, and other organisms. Owing to the general uniformity of its lithological characters, the yellow tuff has not furnished any satisfactory evidence of a definite order of succession in the eruptions to which it was due. In spite of prolonged denudation and of successive later volcanic vicissitudes, it is still possible to recognize some of the separate vents from which the tuff was discharged, such as the islet of Nisida, the hills of Posillipo, Vomero, Capodimonte, and Camaldoli and Gauro.

III. After the discharge of the yellow tuff from numerous cones and craters scattered over the sea-floor where the Campi Phlegræi now extend, the volcanic tract appears to have been upraised into land, and to have been thereafter exposed to a prolonged period of subaerial denudation. But the volcanic activity was not extinct, for

a number of vents made their appearance and discharged a succession of fragmental materials, which differ from the yellow tuff in showing both macroscopically and microscopically a greater variety of composition, and in the proofs which they furnish of a succession of eruptions both in space and time and a gradual southward shifting and diminution of the vigour of the eruptive energy. The largest and most ancient of the volcanoes of this latest period is that of Agnano, the crater of which is built up of layers of pumice, ashes, lapilli, soft grey tuff, and beds of scoriæ. Not improbably it was from this eruptive centre that the trachy-andesitic lava of Caprara issued. Other volcanoes of the same series are Astroni, Solfatara, the two small vents of Cigliano and Campana behind the north-western slopes of Astroni, the last-named example showing three concentric rings, within the innermost of which a beautifully perfect little crater marks the last efforts of this vent. The crater-lake of Avernus belongs likewise to the latest group, and perhaps it was the water percolating from this basin to the thermal springs of Tripergole which, in September, 1538, gave rise to the explosion that built up Monte Nuovo, the youngest of the cones of the Phlegræan Fields.

CORRESPONDENCE.

THE BASE OF THE KEUPER IN SOUTH DEVON.

Sir,—In replying to Dr. Irving's article in your April number, I must preface the same by regretting my use of the term "dolomitic" which somehow crept in; but which, I think, hardly amounts to a "caricature" of his description. I would further add that I never doubted the existence of the fault at the Chit rock.

On the main issue I still hold that the Otterton Breccias are not again brought up on the east side of the river Sid; and that the beds here described as such, occupy a much higher horizon, being separated from the former by a considerable thickness of red sandstones. On this point, however, I am willing to wait—with an open mind—the results of other observers who may choose to devote their attention to this matter.

Alex. Somervail.

Torquay N.H. Society.
16*th April*, 1904.

MARINE FOSSILS IN UPPER COAL-MEASURES.

Sir, — On the 23rd April I found in the Craigmark Burn, Dalmellington, Ayrshire, some marine shells in the Upper Coal-measures. They occur in a cliff on the right bank of the stream, about half a mile up from the village of Craigmark. The cliff is about 30 feet high, its upper part composed of dark shale, and its lower part of lighter-coloured shale with nodules and bands of 'curly' ironstone. About the middle of the cliff there is a 9 inch band of bituminous shale with fish-remains, and in the centre of it the marine band occurs.

The fossils are dwarfed and starved-looking, but from their perfect preservation they have evidently lived on the spot where now found, and occur with a few indistinguishable plant-remains. The following are the species I collected:—*Productus semireticulatus*, var., largest one ½ inch, but generally much smaller; common. *Athyris ambigua*, largest ¾ inch; scarce. *Lingula mytiloides*, rare, and very small. The late R. W. Skipsey many years ago found marine shells in the Coal-measures near Coatbridge, but the specimens were of fair size.[1]

The marine shells I obtained on the 23rd April appear to be pretty high up in the coal strata; and in the stream and on the side of the glen may be seen the Gillyhole Coal, at this part converted into columnar carbonite four feet thick by a small Trap sill; it is one of the finest examples of a 'burnt coal' bed in the west of Scotland. In the same glen there is also a small sill which has assumed a spheroidal structure. I saw no specimens of *Carbonicola* or any other Coal-measure shells in the marine band. I am sending some specimens to the British Museum.

J. Smith.

Monkridding, Kilwinning.
25th April, 1904.

OBITUARY.

PROFESSOR CHARLES EMERSON BEECHER, Ph.D.

Born October 9, 1856. Died February 14, 1904.

(WITH A PORTRAIT: PLATE X.[2])

By the death of Professor Beecher, American palæontology and geology have sustained a great loss, and one which is also sincerely felt by many friends and fellow-workers in England and on the Continent. Although only 47 years of age, he had attained to a high degree of eminence in his University as a teacher and lecturer, whilst his published researches, especially on Trilobites, the Merostomata, and Phyllocarida, entitled him to the first rank as an original investigator in palæozoology; nor had he neglected the higher forms of extinct life, as is shown by his reconstruction of Dinosaurs in the Peabody Museum at Yale.

Charles Emerson Beecher was born at Dunkirk, New York, Oct. 9th, 1856. He was educated in the High School at Warren, Pa., and graduated at the University of Michigan, taking his B.S. in 1878. During the ten succeeding years he was engaged as an assistant to the veteran geologist, Professor James Hall, upon the staff of the Geological Survey of the State of New York, and many specimens now exhibited in the State Museum at Albany testify to his ability as a collector and his skill in developing and mounting invertebrate fossils.

Professor Beecher was appointed in 1888 to the charge of the invertebrate fossils in the Peabody Museum, under the late Professor

[1] Trans. Geol. Soc. Glasgow, vol. ii, p. 52.

[2] For permission to reproduce Professor Beecher's portrait we are much indebted to Mr. J. McK. Cattell, of *The Popular Science Monthly* Garrison on Hudson, New York, U.S.A.—Edit. Geol. Mag.

CHARLES EMERSON BEECHER, PH.D.,

YALE UNIVERSITY.

O. C. Marsh, and in 1889 he received the degree of Ph.D. from Yale University for his memoir on the Brachiospongidæ, a remarkable group of Silurian sponges. In the July of this year he made his first geological trip to the far West, being sent by Professor Marsh to join a party of collectors in Converse County, Wyoming, where he remained till September. During this trip he obtained one of the largest complete skulls of *Triceratops*, now in the Yale Museum. Shortly after this Professor Marsh arranged for Dr. Beecher to visit England and make studies in the British Museum, accompanied by the late Dr. Baur. [Here he made the writer's acquaintance, and became an intimate friend and correspondent respecting their mutual studies upon the Arthropoda.—H. W.] He also, with Dr. Baur, visited France and Germany. During the preparation for his degree at Yale, Beecher had taken geology under the late Professor Dana, and in 1891–92, when the latter was ill, Professor Beecher conducted the classes in geology for him. In 1892 he was made Assistant-Professor of Historical Geology in the Scientific School, holding the post till 1897, when he was appointed Professor of Historical Geology and a member of the Governing Board in the Sheffield Scientific School. On March 10th, 1902, he was made University Professor of Palæontology at Yale.

Professor Charles Schuchert writes: — "In 1893 there was discovered in Lower Silurian shales near Rome, New York, a thin band not more than one-fourth of an inch thick, in which nearly all the Trilobites (*Triarthrus* and *Trinucleus*) preserve antennæ and legs. Trilobite legs had been known before in a few isolated and very imperfectly preserved specimens, and from a series of about 250 sections cut from more than 3,000 enrolled individuals of a species found near Trenton Falls. Antennæ had not previously been seen. This important discovery by a local worker induced Professor Beecher to take out several tons of the shale, and later many hundred individuals were developed by mechanical means to show the ventral anatomy. But few can appreciate the great amount of time and the remarkable skill required to free these Trilobites from the adhering black shale, and to Beecher we owe our detailed knowledge of the ventral anatomy of *Triarthrus* and *Trinucleus*. He published thirteen papers on these very primitive Crustacea, including a classification in which all Trilobites are arranged in three orders." [Special mention should also be made of his enlarged models of the appendages of *Triarthrus*, and of the great *Stylonurus Lacoanus*, which are most valuable and instructive for Museums.—H. W.] "He was at work on an extensive treatise on these forms, in which he proposed to bring together all that is known regarding their anatomy. Unfortunately, this work had not progressed beyond the mechanical stage of preparation of material and the making of drawings."

In 1899 Professor Beecher succeeded the late Professor O. C. Marsh as curator of the entire geological collections in the Peabody Museum at Yale, and became a member of the Board of Trustees of that Museum. He also held the position of Secretary to the Board,

and was a member of the Executive Committee. He was elected a member of the National Academy of Sciences, a Foreign Correspondent of the Geological Society of London, and a Fellow of the Geological Society of America. In 1900 he was elected President of the Connecticut Academy of Arts and Sciences, and filled the office for two years.

"In 1899 he presented his entire collection of fossils, containing upwards of 100,000 specimens, to Yale Museum. The gift was without conditions, and was given 'in grateful recognition of the honours and favours conferred upon me during my connection with the University.'

"Although Professor Beecher was interested in stratigraphic and descriptive palæontology, he published almost nothing in either branch of the science. Of stratigraphic and faunal papers he has five. Of new species apparently not more than thirty-one were described by him. Besides these he proposed seven new genera and seven new orders.

"His most philosophic paper, and the one which he himself thought best, is entitled 'The Origin and Significance of Spines. A study in evolution.' He states here that all spinose species when young are devoid of spines, and are derived from non-spinose ancestors. Forms attaining the limit of spine differentiation leave no descendants, and out of spinose types no new types are developed.

"Charles E. Beecher's scientific writings amount to about sixty-five in number. His standing among biologists and palæontologists was high, and he was the leader among the students of Brachiopoda and Trilobita. His palæontological work at Yale was essentially of a biological and philosophical character. As a preparator of fossils he had no equal, and as a collector was one of the best. He had the artistic temperament, and made most of the illustrations for his publications. He was a slow and very careful worker. Those who knew him well saw in him an enthusiast, but his exuberance was always held in check by his judicial qualities, which character made him also an excellent counsellor. He travelled extensively, read wisely, was a lover of the English masters and of Herbert Spencer's philosophy. He was orderly in his work, and, as he had the 'museum instinct' well developed, he made one of the best of museum curators."—*Professor Charles Schuchert.*

His past students bear the highest testimony to his worth as a teacher in science, both as a lecturer and as a demonstrator in the laboratory. As a friend, all who knew him appreciated his many excellent qualities and his sterling worth.

[Kindly favoured by Miss Lucy P. Bush from the *Yale Alumni Weekly*, New Haven, Conn., March 2nd, 1904.]

SIR CLEMENT LE NEVE FOSTER, D.Sc., F.R.S.

Born March 23, 1841. Died April 19, 1904.

In the death of Sir Clement Foster we mourn the loss of a geologist the most distinguished in this country for his scientific and practical knowledge of metalliferous mining, and of all matters relating to stone quarries and slate-mines.

The second son of Peter Le Neve Foster (for many years Secretary of the Society of Arts), he was born at Camberwell, and received his early education at Boulogne and Amiens. He then studied successively at the Royal School of Mines and at the Mining College of Freiberg, in Saxony, and eventually took the degree of Doctor of Science at the University of London.

In 1860 he was appointed an Assistant Geologist on the Geological Survey, working for a few years in the Wealden area and among the Carboniferous rocks of Derbyshire. Conjointly with his colleague William Topley, the now classic paper "On the Superficial Deposits of the Valley of the Medway, with remarks on the Denudation of the Weald," was read before the Geological Society in 1865. The authors sought to prove that old gravel of the Medway occurs 300 feet above the present level of the river, and that, granting this to be the case, there was no difficulty in admitting that the present features of the Wealden area were sculptured by rain and rivers. Later on Foster was part author of the Memoir on the Geology of North Derbyshire (Geol. Survey, 1869). He retired from the Geological Survey in 1865, not without much personal regret at leaving the congenial and active field-work of that institution; he retired simply because the prospects of earning a reasonable income were too remote. He now devoted his attention especially to mineralogy and mining—lecturing on these subjects in Cornwall, and examining several important mineral districts in different parts of the world. He brought before the Geological Society notes on Celestine in Egypt (with H. Bauerman), and an account of the Caratal goldfield in Venezuela. In 1872 he was appointed an Inspector of Mines under the Home Office, and served for about eight years in the south-west of England. The results of his observations on mines in Cornwall and Devon were brought before the Geological Society and before local Societies in Cornwall. In 1880 he was given charge of the North Wales district, and resided at Llandudno until his retirement from the Home Office in 1901. Meanwhile, on the death of Sir Warington Smyth, Foster was appointed in 1890 to the professorship of mining at the Royal College of Science, a post which he held until the time of his death. The work of his later years is largely embodied in the Reports on Mines and Quarries issued annually by the Home Office. He was author also of an important treatise on "Ore and Stone Mining," of which five editions have been issued, and only last year he published an excellent handbook on "The Elements of Mining and Quarrying."

His wide knowledge and the charm of his personal character made him known and beloved by a large circle of friends, while his services on committees and as a juror were in frequent request. His last important function was as a member of the present Royal Commission on Coal supplies. He was elected a Fellow of the Royal Society in 1893, and last year the honour of knighthood was conferred upon him.